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81-37

A/TSC Project Evaluation Series

State of the Art of Current Practices For Transit Transfers

DEPARTMENT OF
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Final Report
July 1981

Service and Methods Demonstration Program

U.S. DEPARTMENT OF TRANSPORTATION
Urban Mass Transportation Administration and
Research and Special Programs Administration
Transportation Systems Center

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16. Abstract

The major objectives of this study are to: 1) describe and summarize the transfer policies currently in use on U.S. transit properties; 2) identify reasons why properties use or do not use particular transfer policies; 3) determine the consequences of alternative transfer policies in different settings; and 4) analyze and identify situations or settings in which particular transfer policies can be applied beneficially.

A transfer policy consists of a set of operator actions involving vehicle routing and scheduling, transfer charges, information for passengers, and terminal facilities, which affects the movement of passengers between transit vehicles as part of a continuing trip. This study examines the current use and impacts of eleven potential transfer policy components related to these operator actions. The effects of each component on operator costs, user satisfaction, ridership, and revenue, are related to such site-specific factors as historical and current patterns of passenger flows, route structure, service frequency, shape and size of the service area, layout of the central business district, and degree of schedule adherence. Based on these relationships, the situations or settings in which particular transfer policies can most beneficially be applied are identified.

Data for this study were drawn from a series of telephone and on-site discussions with experienced transit professionals on 39 different U.S. transit properties for bus/bus, bus/rail, and rail/rail transfers. The information resulting from these discussions has been supplemented with references to the literature as appropriate.

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PREFACE

This study of transit transfer policies was prepared in the Boston, Massachusetts office of Charles River Associates Incorporated (CRA) for the Transportation Systems Center (TSC) of the U.S. Department of Transportation (DOT) under Contract Number DOT-TSC-1406, as part of the Service and Methods Demonstration (SMD) Program, sponsored by the Urban Mass Transportation Administration (UMTA). Michael Nelson served as CRA's Study Manager and Principal Investigator. Robert Casey of TSC served as Technical Advisor and Monitor for the study while Stewart McKeown was the UMTA Study Manager.

Many individuals contributed to the successful completion of this study. The CRA study team was supervised by Daniel Brand, CRA's Officer-in-Charge, who contributed much of the initial study design, as well as substantive reviews and revisions of study outputs. Michael Nelson directed the study on a day-to-day basis and was responsible for the preparation of this report. Michael Mandel conducted the interviews with transit professionals, performed most of the subsequent analyses, and contributed draft material throughout this report. Thomas Parody participated in initial study design and planning activities, while Jean Belding organized and edited this report. Other major CRA contributors included Mary Ann Buescher, Janet Fearon, Robert Scheier, and Kathryn Davenport, Publications, and Diane Kemski, secretarial.

Although CRA accepts full responsibility for the information presented in this report, the study would not have been possible without the cooperation and assistance of many other individuals. In particular, Robert Casey (TSC) provided many helpful observations and coordinated the reviews of the draft report conducted by UMTA staff and others. The innumerable and invaluable contributions of time and insights by the many transit professionals who participated in this study are also gratefully acknowledged.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	milss	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square fset	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	squars kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grame	g
lb	pounds	0.45	kilogrems	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teespoone	5	milliliters	ml
Tbsp	teblespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fehrenheit temperature	5/9 (after subtrecting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	squere inches	in^2
m^2	square meters	1.2	squere yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilogrems	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then edd 32)	Fahrenheit temperature	°F

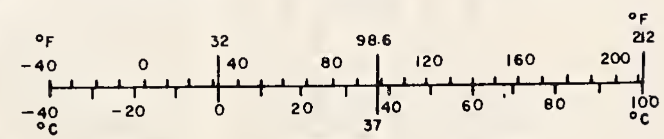

TABLE OF CONTENTS

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Introduction

This study investigates the cost, ridership, revenue, and user satisfaction consequences of alternative transit transfer policies. A <u>transfer policy</u> consists of a set of operator actions involving vehicle routing and scheduling, transfer charges, information for passengers, and terminal facilities, which affects the movement of passengers between transit vehicles as part of a continuing trip. Under ideal circumstances, transit would carry all users directly from their origins to their destinations without requiring a change of vehicles. However, given the geographic and temporal distribution of trips, such direct service is of course uneconomical for transit to provide. Therefore, operators must undertake some set of actions (a "transfer policy") to serve transferring passengers.

This study has the following major objectives:

- To describe and summarize the transfer policies currently in use on U.S. transit properties;
- To identify reasons why properties use or do not use particular transfer policies;
- To determine the consequences of alternative transfer policies in different settings; and
- To analyze and identify situations or settings in which particular transfer policies can be applied beneficially.

Study Approach

The information in this report pertains to bus/bus, bus/rail, and rail/rail transfers.[1] It has been collected through a series of telephone and on-site discussions with experienced transit professionals on 39 different properties. These discussions have elicited informed operator opinions and results of previous on-site studies concerning the effects of alternative transfer policies. Discussions were held with operators of a cross-section of U.S. transit properties, encompassing a wide variety of environments, attitudes, and policies. Particular care was taken to include properties that had implemented noteworthy transfer policy initiatives. Literature is also referred to whenever appropriate.

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[1] In general, bus/bus transfers will be referred to simply as "bus" transfers, while transfers involving rail as either the originating or connecting mode (or both) are "rail" transfers. In this study, "rail" includes rail rapid transit as well as commuter rail.

Identifying the multiple effects of a particular transfer policy is made possible by studying transfer policy components individually first, and then in combination when their effects interact or when they are logically used together. Transfer policy components are the basic building blocks that make up transfer policies. Eleven transfer policy components are examined in this study:

A. Routing Components
   1. Distance between routes at transfer points;
   2. Through-routing;

B. Scheduling Components
   3. Schedule coordination;
   4. Dynamic control of departure times at transfer points;
   5. Timed transfers;
   6. Schedule adherence on connecting routes;
   7. Service frequency on connecting routes;

C. Pricing Components
   8. Transfer charge;
   9. Use of transfer slips;

D. Information Components
   10. Provision of schedule information;
   11. Marketing initiatives.

These transfer policy components do not exhaust the list of possible operator actions that affect transfers. The remaining ones (such as transit shelters, terminal facilities, and temporal/directional restrictions) were omitted from the scope of this study at the outset due to limited study resources. However, they are reviewed briefly in conjunction with several of the above components.

Summary of Results

For each of the transfer policy components listed above, there may be a number of distinct variations that are unique in their scope or impacts. In Figure ES-1, the operator effort, cost, user satisfaction, ridership, and revenue consequences of each of these variations is summarized. Each variation is described in this executive summary in separate sections below for each transfer policy component.

On any particular transit property, the demand for transferring clearly influences the type of transfer policy adopted. Relevant transfer demand characteristics include the following:

- The percentage of riders who transfer (i.e., "transfer rate");
- Their socioeconomic and trip purpose characteristics;
- Transfer point locations; and
- Directional and temporal characteristics.

The transfer rate is the percentage of transit person-trips which involve transfers between transit vehicles. Often, the transfer rate cannot be calculated directly from available data, but rather must be estimated from transfer slip data, passenger counts, or special surveys. Data problems include transit pass users who do not utilize transfer slips, or riders who transfer more than once in the course of a trip. In general, however, it is possible to obtain reasonable estimates of transfer rates on most properties.

For bus/bus transfers, the average transfer rate on the properties interviewed is approximately 21 percent. Several properties have a transfer rate on the order of 5 percent, while transfer rates as high as 50 percent were observed. The

Figure ES-1

SUMMARY OF STUDY FINDINGS

Option	Operator Effort	Cost	User Satisfaction	Ridership	Revenue
DISTANCE BETWEEN ROUTES AT TRANSFER POINTS					
Bus					
Central On-Street Transfer Point or Area	o	o	⊠	⊠	⊠
Off-Street Transfer Facility	x	x	x	⊠	⊠
Transit Mall	⊠	⊠	x	⊠	⊠
Sub-Foci (bring routes together outside central area)	o	o	⊠	⊠	⊠
Grid	⊠	o	⊠	⊠	⊠
Rail					
Horizontal Distance					
Vertical Alignment of Bus and Rail Routes to Reduce Horizontal Distance	⊠	⊠	⊠	⊠	⊠
Bus Ramps into Station	x	x	⊠	⊠	⊠
Bus Clustering at Street Level	⊠	⊠	⊠	⊠	⊠
Vertical Distance					
Reduction of Vertical Distance	x	x	x	⊠	⊠
Reduction of Perceived Vertical Distance (elevators/escalators)	x	x	⊠	⊠	⊠

Table continued on following page.

Figure ES-1 (Continued)

SUMMARY OF STUDY FINDINGS

Option	Operator Effort	Cost	User Satisfaction	Ridership	Revenue
THROUGH-ROUTING					
Bus					
Interlining or "Classic" Through-Routing	o	o	⊠	⊠	⊠
Single Route Through-Routing	o	o	⊠	⊠	⊠
Variable Through-Routing	⊠	o	o	o	o
"Trippers"	o	o	o	o	o
Overlap	o	⊠	⊠	⊠	⊠
Rail					
Route Consolidation	⊠	-x	-⊠	-⊠	-⊠
SCHEDULE COORDINATION					
Bus					
CBD	o	o	⊠	⊠	⊠
Trunk-Crosstown	o	o	⊠	⊠	⊠
Minor	o	o	o	o	o
Rail					
Rapid Rail-to-Bus	o	o	o	o	o
Commuter Rail/Bus	o	o	o	o	o
Rail/Rail	o	o	o	o	o

Table continued on following page.

Figure ES-1 (Continued)

SUMMARY OF STUDY FINDINGS

Option	Operator Effort	Cost	User Satisfaction	Ridership	Revenue
DYNAMIC CONTROL					
Bus					
Alone	o	o	o	o	o
With Other Options	⊠	⊠	⊠	⊠	⊠
Rail					
Informal Holding	o	o	o	o	o
Formal Meeting	⊠	⊠	o	o	o
Formal Holding	⊠	⊠	o	o	o
TIMED TRANSFERS					
Bus					
Simple Timed Transfer	o	o	⊠	⊠	o
Pulse Scheduling	⊠	⊠	⊠	⊠	⊠
Line-Up	⊠	⊠	⊠	⊠	⊠
Neighborhood Pulse	⊠	⊠	⊠	⊠	⊠
Rail	⊠	⊠	o	o	o
SCHEDULE ADHERENCE (+)	x	⊠	⊠	⊠	⊠
SERVICE FREQUENCY (+)	⊠	x	x	x	x
TRANSFER CHARGE (+)	o	o	-⊠	-o	o
USE OF TRANSFER SLIPS	o	⊠	o	o	o
Bus	o	⊠	o	o	o
Rail	⊠	x	o	o	o

Table continued on following page.

Figure ES-1 (Continued)

SUMMARY OF STUDY FINDINGS

Option	Operator Effort	Cost	User Satisfaction	Ridership	Revenue
SCHEDULE INFORMATION	o	o	o	o	o
MARKETING	o	o	o	o	o

CODE:

x	Has large effect in most settings.
⊗	Effect varies substantially depending upon setting.
o	Usually has a minor effect.
-	Negative effect in given impact area (e.g., -x in second column means major reduction in cost).

size of the property has a large effect on the overall transfer rate. Not including properties that currently use timed transfers extensively, large bus properties have a much higher average transfer rate than small properties (20 percent versus 12 percent). Bus properties which currently use timed transfers extensively are uniformly small properties, and have a much higher transfer rate (28 percent) than either large or small nontimed transfer cities. Also, bus properties that do not charge for transfers have a higher average transfer rate than those that do (22 percent versus 18 percent). In many of these cases, the causal relationship is not clear. That is, rather than the action causing a higher transfer rate, the presence of a high transfer rate may cause a property to institute options such as timed transfers or a zero transfer charge.

For bus/rail transfers, the transfer rate tends to be much higher than for bus/bus transfers, with an average rate of 47 percent observed on the properties interviewed. Most bus/rail transfer rates are in the range of 40 to 50 percent, except for New York City (16 percent), where the heavy rail coverage in Manhattan and parts of Brooklyn allows passengers to walk to and from the subway.

Riders themselves who transfer vary by socioeconomic and demographic groups. Low-income riders transfer more often than higher-income riders on today's U.S. transit properties. A reasonable rule of thumb is that riders with household incomes below $15,000 (in 1980) have a transfer rate about one and one-half times as high as riders with household incomes above that figure. Young people also have above average transfer rates. Elderly people, on the other hand, tend to have a lower transfer rate than other riders, perhaps because of the effort involved in changing vehicles associated with transfers.

The following sections summarize the findings of the study for each of the 11 transfer policy components outlined above. Within each section, the current practices of transit operators regarding the component are described and tabulated. Reasons offered by operators for the use or lack of use of the policy component are examined, and the cost, user satisfaction, ridership, and revenue consequences of the component when used in different settings are provided. In this way, the types of properties and settings for which the transfer policy component is most beneficial are identified, along with other components, which work well when combined with the component in question.

Distance Between Routes at Transfer Points

A basic attribute of transferring is the walk required between vehicles. There may be only a few feet, or alternatively, passengers may have to walk several blocks to transfer. The greater the distance, the less useful the transfer is for the passenger.

Bus Transfers

Approximately one-third of the bus properties participating in this study separate by 500 feet or more some routes between which transfers are expected to occur. On at least one property, passengers must walk up to 1,500 feet to transfer. The major factors affecting spatial separation are the number of intersecting routes and the layout of the CBD, with the second factor potentially more important than the first.

Alternatives available to the operator relating to spatial separation at transfer points include:

- Routing buses on the basis of operational and nontransferring demand considerations only (the "do-nothing" alternative);
- Placing all routes within one or two blocks of each other when physically feasible;
- Building an off-street terminal facility;
- Establishing a bus transit mall;
- Collecting route termini into several subfoci such that all or most routes intersect, though not all at the same point; or
- Laying out routes in a grid network.

The principal cost consequences of any of these strategies typically arise from the changes in bus VMT needed to move the routes closer together. On the demand side, key aspects of transfer distance are walk time, comprehensibility of the transfer system and potential pedestrian obstacles. Reducing transfer distance may have significant effects on user satisfaction and ridership. The groups most affected by spatial separation are the elderly, shoppers, and infrequent users.

Rail Transfers

Rail transfer distances are typically lengthier than the distances for bus transfers. These transfers often involve vertical as well as horizontal separation between routes. The path between vehicles is not necessarily direct, as it usually is for bus/bus transfers. Buses may line up in a long row to discharge their passengers at substantially varying distances from the rail entrances, turnstiles or rail platforms. Rail train lengths can be quite long (e.g., up to 600 feet in New York City), affecting the distance that alighting passengers must walk to stairs, escalators, station exits and bus loading

bays. The characteristics of available facilities, construction constraints in and around current rail stations, and the relatively low priority typically assigned to the spatial separation problem in the rail context often lead to long rail transfer distances.

Alternatives available to the operator for dealing with the spatial separation associated with rail transfers include the following:

- Letting vehicles stop at the nearest convenient location given existing rail facilities (the "do-nothing" alternative);
- Providing convenient passenger access (e.g., using elevators/escalators) to grade-separated structures;
- Bringing buses directly over or under the rail platform;
- Bringing buses up or down to the same elevation as the rail platform;
- Bringing buses into the rail station to reduce horizontal separation; and
- Building on- or off-street terminal facilities, etc., to bring buses closer together at the street level.

This list does not include actions which involve changes in the rail right-of-way itself. That is, both the vertical grade separation and the horizontal alignment of the rail line(s) are taken as given.

The running cost consequences (bus VMT and VHT) of reducing spatial separation for rail transfers do not differ substantially from the running cost consequences associated with bus transfers. However, actions for reducing rail transfer distances may entail major capital costs due to the facility changes involved. Capital costs are likely to be prohibitive if retrofitting of existing stations is contemplated, but will be much smaller if the distance reduction action is incorporated in the station's original construction.

The demand-side consequences of reducing spatial separation are similar in the bus and rail cases. While rail transfers may be somewhat less onerous than bus transfers because of the amenities and shelter often provided by rail facilities, the importance of the vertical transfer distance typically encountered in rail transfers to some market segments makes spatial separation a particularly important component of a rail transfer policy.

For both bus and rail transfers, physical constraints on route placement and new construction, the type of transfer, characteristics of transferees, and the existing transfer rate are the major determinants of the tradeoff between costs and benefits. In addition, the nature of other components in the transfer policy is also important, since in practice reduction of spatial separation is a prerequisite for other transfer policy components that require the physical proximity of connecting vehicles (such as schedule coordination, or timed transfers). Therefore, reducing spatial separation may have benefits associated with other components, as well as being potentially beneficial as a separate option.

Through-Routing

Through-routing, also known as interlining, involves linking two routes so that the same vehicle travels on both routes. It eliminates transfers between the two routes, since a passenger can board a vehicle at a stop on one route and get off at a stop on the other without having to change vehicles. A number of U.S. transit properties use through-routing for both ridership and operational reasons, with some properties using it quite extensively.

Bus Transfers

Five types of bus through-routing are currently in use:

- Interlining, or "classic" through-routing: Two seperately identified routes share the same vehicles;

- Single route through-routing: Differs from classic through-routing only in that the two "halves" of the route are joined on a permanent basis, and are formally treated as a single route;
- Variable through-routing: Differs from classic through-routing in that buses are exchanged among multiple routes rather than just between pairs of routes;
- Trippers: Buses are through-routed at particular times of the day, usually during rush hour or to meet shift or school times; and
- Overlap: Involves terminating a radial route on the opposite side of the CBD from which it came in.

Typically, through-routing lowers costs by eliminating expensive downtown turnarounds. However, there is a possibility that costs will increase due to the need to match headways on interlined routes and/or due to increases in bus revenue miles due to possible overlap. Reliability should remain the same in most cases if layovers are not eliminated. Indeed, reliability can increase if routes are properly paired.

User satisfaction and ridership will usually increase with the implementation of through-routing. A reasonable range for the increase in ridership for a pair of routes that connect logical origins and destinations is between 4 and 7 percent of the original ridership on the two routes. However, pairing routes that do not connect logical origins and destinations may not increase ridership at all.

Rail Transfers

In theory, a bus could be driven over a street-based route, and then, using a second set of (steel) wheels, traverse some line-haul rail segment. To date, however, conventional street buses have not been adapted for rail use on a widespread basis. Therefore, "dual-mode" operation is not considered further here.

The most significant option of this type relevant to rail transfers is route consolidation. Route consolidation is the exact opposite of through-routing, and entails the turning back at rail stations of bus (or commuter rail) routes that formerly traveled into the CBD. Route consolidation thus forces riders to transfer by making the rail lines the only transit access route into the CBD. Several cities use route consolidation extensively, and turn back all or almost all of their buses at rail stations, while other cities do not use this option at all.[1]

Route consolidation can have a strong beneficial effect on cost due to reductions in bus miles and hours. Moreover, the miles eliminated are likely to be in the most congested areas, thereby increasing cost savings. Turnaround mileage is not eliminated (in contrast to classic through-routing), but is moved well out of the most congested areas, thus providing a further cut in VHT. Since route consolidation typically affects a large number of routes, it is clear that this option has considerable potential for cost savings.

User satisfaction is affected by route consolidation in several ways. On the negative side it requires a transfer where none existed before, and forces individuals who might prefer at-grade buses (such as the elderly) to use rail. In an important sense, route consolidation must decrease "average" user satisfaction, because in the absence of bus turnbacks, the rider had the option of transferring at the rail station.

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[1]Route consolidation can also be practiced for bus/bus transfers. That is, express buses can be operated only on the line haul portion of the trip, with separate feeder bus service. However, the disutility of transfers in general, the opportunity for through-routing with buses, and the fact that all buses generally have comparable capacities combine to limit the applicability of this option.

however, the pivotal factors in determining whether user satisfaction are significantly decreased are the quality and reliability of the rail line. On the positive side, bus-to-rail transfers are generally perceived to be less onerous than bus-to-bus transfers, and average trip time may be reduced if rail service is faster than the bus.

The decision to implement route consolidation necessarily weighs the cost of providing parallel service against the possible decrease in user satisfaciton caused by forcing people to transfer and by eliminating or drastically curtailing local service between rail stops. Route consolidation may be a dominant option in cases where the CBD and the corridor leading into the CBD are so congested that bus speeds are significantly lower than rail, or where rail trips are sufficiently long so that even small advantages in operating speeds are translated into major time savings.

Operating a competitive parallel bus service becomes a reasonable alternative if the rail line has such a low frequency that lengthy transfer times are possible when transferring from bus to rail, or if the rail line is unreliable, unattractive, or short in length. Clearly, the merits of route consolidation depend upon the attitudes and motivations of the service provider, as well as numerous site-specific conditions and factors.

Schedule Coordination

Schedule coordination involves the adjustment of schedules on routes to change the relative times of arrival of vehicles at transfer points to reduce average transfer wait time. Schedule coordination used alone benefits passengers transferring in one direction more than passengers transferring in the other, since to ensure that one vehicle arrives before another without disruption of the regular schedule, an offset

must be used (rather than attempting to have two vehicles meet at the exact time). Hence, schedule coordination used alone is applied most beneficially to route pairs where the majority of transfers are in a single direction at any one time.

Bus Transfers

Schedule coordination for buses generally takes one of three forms:

- CBD schedule coordination: Used in situations where there is a strong directional flow of transfers through the CBD during peak hours;
- Trunk-crosstown coordination: Involves transfers between trunk lines and crosstowns where the schedule coordination is imposed on the low-frequency crosstown lines; and
- Minor schedule coordination: Characteristically implemented in response to the complaints of passengers on a particular bus who are unable to make a connection to another route.

The cost consequences of schedule coordination result from the adjustments in headways made to match the two routes. User satisfaction will increase for all transferring riders "going in the direction" of the coordination. Overall ridership gains are likely to be on the order of 3 to 4 percent for CBD schedule coordination, 1 to 2 percent for trunk-crosstown coordination, and minimal for minor schedule coordination.

Schedule coordination is applicable whenever transfers are strongly directional between two lines. In such a situation, schedule coordination may be a cost-effective way to improve service, since it typically costs little, can involve only minor headway changes, and demands little of an operator's time or attention.

Rail Transfers

When schedule coordination is used for rail transfers, it generally takes one of three forms:

- Rapid rail-to-bus: Typically used at outlying rail stations in the evening, often in conjunction with dynamic control (see next section);
- Commuter rail/bus: Similar to rapid rail-to-bus, but may require dedicated bus runs and greater administrative effort due to different operating authorities; and
- Rail/rail: Used on intersecting routes (as opposed to local and express routes in parallel operation) when frequencies are low.

Using any of these options typically will entail some planning and administrative costs, and may affect operating costs if headway adjustments are made. User satisfaction, ridership, and revenue should increase due to the reduction in average transfer time. As in the case of bus transfers, the applicability of schedule coordination depends on the directionality of transfers. The characteristics of rail facilities and problems of interagency coordination are also potentially important considerations.

Schedule coordination is relatively uncommon in rail transit operations (compared to the number of possible opportunities) for several reasons. First, rapid rail headways are usually so short that schedule coordination could not produce significant reductions in transfer time. Also, in cases where the distance (vertical or horizontal) between connecting vehicles is long and/or variable (e.g., different parts of the rail platform differ significantly in their distance from the bus stop), the variance across passengers of transfer walk time may make it necessary for the "advances" needed to ensure a timely transfer between vehicles for most passengers to be longer than in the bus/bus case. Thus, the

benefits that accrue through use of this option are lower in the rail case. Problems caused by separate bus and rail scheduling departments and multiple intersections among bus and rail routes further limit the applicability of this option.

Dynamic Control of Departure Times at Transfer Points

Dynamic control involves holding a vehicle beyond its scheduled departure time from a transfer point if it is known that a vehicle on another route is approaching which is likely to have transferring passengers on board. Such information can be conveyed by radio or by some other signaling device (e.g., headlights).

Bus Transfers

Dynamic control is found in many different settings. Several small properties use it extensively, either to control meetings between trunk and crosstown routes or to facilitate transfers in CBDs where the schedule permits. Some larger properties use dynamic control marginally, on only a few routes or only in the evening. However, on smaller properties using timed transfers, dynamic control is regularly used to ensure the meeting of buses at the transfer point.

The cost and operational consequences of dynamic control tend to be minor: Operators see it as an added service not requiring extra layover time to absorb the added schedule uncertainty it may induce. User satisfaction of riders aided in making their connection by dynamic control will increase, at the cost of possible reductions in user satisfaction of the other riders. Generally, the ridership consequences of dynamic control alone are not significant, but in combination with other options (such as timed transfers), dynamic control can contribute substantially to ridership gains.

The principal tradeoff involved in dynamic control is the gain in satisfaction for transferees versus potential downstream disruptions to schedule adherence. Therefore, as a stand-alone option, dynamic control is appropriate either when transfer flows are intermittent or schedule unreliability is common. Its use is constrained principally by the size and complexity of the system.

Rail Transfers

Almost all rail properties use dynamic control at some bus/rail transfer points, and a few use it at rail/rail transfer points as well. The basic rationale behind dynamic control involving rail is the same as for dynamic control of bus transfers, though communications equipment and procedures may vary. Dynamic control in the bus/rail context is almost invariably applied to bus rather than rail vehicle movements, thus facilitating rail to bus transfers. This is due to the typically higher frequency of rapid rail, which minimizes the benefits attainable from holding rail vehicles, problems of interagency coordination, and the possibility of creating systemwide operational disruptions.

Dynamic control of bus/rail transfers generally takes one of three forms:

- Informal holding: Possibly without using formal communications methods, the bus waits at the transfer point based on the anticipated arrival of a train;
- Formal meeting: A bus is formally scheduled to meet a particular train, and will hold until passengers arrive from that train; and
- Formal holding: The bus driver is informed of the pending arrival of a train so that the bus can be held until transferring passengers arrive.

Dynamic control applied to the bus side of rail/bus transfers tends not to have large operational consequences. The effects of holding a bus for a few minutes have already been outlined and are generally minor. Unless buses must hold for unreliable trains, and poor communications exist between bus and rail, dynamic control of buses for bus/rail transfers does not lead to significant operational problems.

Once again, the costs of dynamic control arise from additional layover time and needed signaling equipment. Most properties do not build much additional layover time into the schedule for the purpose of dynamic control since the hold times are usually relatively short. The capital costs of train arrival signals, which are the predominant signaling devices now used for bus/rail transfers, are minor in comparison with other capital outlays. Maintenance costs are also low.

Dynamic control increases user satisfaction by eliminating those occasions when transferring passengers just miss their bus and otherwise would have to wait the full bus headway. However, holding buses for more than a small length of time (e.g., five minutes) may adversely affect the user satisfaction of riders boarding downstream. This effect may be insignificant for buses carrying evening commuter rail riders that only let out passengers, or it may be quite important for buses that must make other connections.

Overall, operators tend to view dynamic control of rail transfers as a sort of public relations measure, and do not attach major ridership and revenue consequences directly to its use. However, its widespread implementation implies that it can be used effectively in a broad range of settings.

Timed Transfers

A timed transfer is defined as a set of operator actions that provides some degree of certainty that vehicles on different routes will meet at regular intervals to exchange transferring passengers.

Bus Transfers

Timed transfers for buses can be divided into four distinct types:

- Simple timed transfers: Two routes are scheduled and operated to guarantee that some or all buses on the routes will meet at the transfer point;
- Pulse scheduling: Buses on all (or most) routes that meet at the major transfer point are scheduled to arrive nearly simultaneously, hold until all buses have come in, and then leave together.
- Line-ups: In larger cities, buses or all (or most) routes that meet at the major transfer point are scheduled to allow a pulse-type exchange of passengers, typically in the context of low-service frequencies and possibly long layovers at the transfer point, and most often in the evening; and
- "Neighborhood" pulse: The schedules of neighborhood circulator routes are coordinated to make travel within a sector of a city easier. Sinple timed transfers are used on many properties, from the smallest to the largest, and are most commonly employed in the evening when both routes have low frequencies. Pulse scheduling is currently found in smaller cities (service area population up to 300,000) and is utilized all day at central transfer points with a normal pulse frequency of approximately 30 minutes. Line-ups are used by many larger, nonpulse properties

(service area population of 500,000 or more), typically with headways of one hour. Neighborhood pulse is currently being implemented on at least two large properties (Portland, Oregon and Denver, Colorado) as part of their conversion to the bus transit center concept.

In general, implementation of timed transfers requires several operator actions. Headways on different routes must be synchronized by altering route length and/or modifying layovers. Extra layover times may be needed to improve schedule adherence. This may also be accomplished by providing dynamic control of buses at the transfer point in case any are late. The operator must provide suitable space and facilities to permit easy simultaneous interchange of passengers between buses, and must make important decisions concerning user information.

Property size is the principal criterion for timed transfer applicability, serving as a proxy for headway reliability, service frequency, and the number of buses meeting at one time. Properties with less than 400,000 people in their service area are generally able to use pulse scheduling at their main transfer point. Larger properties often have line-ups at night. Simple timed transfers are usable on any property, while neighborhood pulse is applicable on any system with subcenters which serve as logical pulse points.

Service frequency and reliability appear to be the major determinants of whether user satisfaction is greatly increased by timed transfers. Ridership gains on the order of 5 to 12 percent appear reasonable with a highly reliable pulse-type timed transfer. Since increasing reliability costs money, the operator can implement timed transfers in different ways depending on local objectives (e.g., increasing layover times and shortening routes versus adding equipment). Overall,

however, timed transfers appear to be a cost-effective way of increasing service and ridership under certain circumstances without necessarily increasing costs.

Rail Transfers

Timed transfers between rail and bus or rail and rail are uncommon for several reasons. First, rail operators are reluctant or unable to adjust rail schedules and ensure that they will be adhered to in the way that timed transfers would require. Second, the high frequency of most rapid rail lines means that scheduling options for bus-to-rail or rail-to-rail transfers will be unprofitable, since expected transfer time to rail is low already. Third, and most important, the larger spatial separation for transferring passengers inherent in most rail operations requires longer layovers at the transfer point, which are costly, disruptive to downstream passengers and upstream operations, inconvenient to through-riding passengers, and generally difficult to control.

This option generally can be used only in the evening or on commuter rail, when frequencies are low, and the reliability of transfers can be guaranteed without excessively costly layovers. The applicability of this option is enhanced if there are across-platform transfers, or buses that are dedicated to meeting the train.

Schedule Adherence on Connecting Routes:
Bus and Rail Transfers

Schedule adherence is an important aspect of overall level of service on transit properties that affects all (transferring and nontransferring) riders on the system. Major causes of bus schedule adherence problems include traffic congestion, bunching, and somewhat surprisingly, interference from trains and breakdowns of new buses. Remedies include skip-stopping,

use of electronic and manual monitoring systems to control bus bunching, passing first bus, and insertion of extra buses. Rail schedule adherence is also a problem, though it may be less important to transferring passengers than bus schedule adherence due to the typically high frequency of rapid rail service, and the amenities/opportunities for other productive activities (e.g., shopping) often found at rail stations. Also, rail service itself tends to be more reliable than bus due to its use of an exclusive right-of-way, though hardware unreliability and the inherent limitations of fixed guideways may produce some exceptions.

For both bus and rail transfers, the principal consequences of increased schedule unreliability are an increase in the variance in transfer wait time and the expected (average) transfer wait time. These, of course, lead to decreases in user satisfaction, ridership, and revenue. However, the direct transfer-related consequences of schedule unreliability are usually dominated by the nontransfer effects. Nevertheless, there are <u>indirect</u> transfer-related benefits which are nontrivial. If unreliability is too high, other operator actions regarding transfers (e.g., pulse scheduling or schedule coordination, are likely to meet limited success. Since the consequences of these other transfer policy options can be very significant, minimizing unreliability for the purpose of aiding transfers can be an important objective.

Service Frequency on Connecting Routes: Bus and Rail Transfers

Service frequency, like schedule adherence, is an important component of transit level of service that has consequences beyond its impact on transfers. Given good schedule adherence, increasing the frequency of service on a

connecting route should decrease the transfer wait time. Typically, however, operators raise or lower service frequency in response to nontransfer-related factors. The exceptions to this rule arise when other transfer components such as timed transfers, through-routing, and schedule coordination are implemented, since headways must be synchronized between routes. Even in these cases, however, the headway adjustments currently made are usually not large.

Also, rail frequencies are almost never changed for the purpose of implementing a particular transfer policy option, for several reasons. First is the typically high frequency of rapid rail, which tends to make other transfer policy options unnecessary when rail is the connecting vehicle. Second, it is often difficult or impractical to change headways, especially on systems which have much interlocking of different routes. Frequency increases may be very costly in terms of manpower and equipment, while frequency decreases are often constrained by demand levels. Furthermore, if the buses and trains are scheduled by different authorities, coordination of service to improve transfer connections may be difficult or impossible. Overall, bus schedules are almost always adjusted to fit a given rail schedule for transfer policy purposes, not vice versa.

For both bus and rail transfers, user satisfaction, ridership, and revenue will rise due to the reduction in transfer wait time associated with service frequency increases. Furthermore, there is a threshold headway of 10 to 15 minutes below which other transfer-related actions regarding scheduling may not be worthwhile due to limits on how great a reduction in transfer wait time they can produce. However, because most changes in headway are not made across this threshold, and because of the significant cost of increasing service

frequency, large changes in service frequency are typically only made in response to overall demand or other factors, and not simply transfer demand.

Transfer Charge

The transfer charge is the amount of money, over and above the basic fare, which a passenger pays to transfer to a second transit vehicle.

Bus Transfers

Most bus properties currently have only a $0.00 or $0.05 transfer charge. Other transfer charge levels are comparatively rare. Very few properties have full-fare transfers.

There is no consistent trend in transfer charges over recent years. Some properties have raised the charge slightly, e.g., from $0.02 to $0.05. Other properties have made transfers free. On average, nominal (and certainly real) transfer charges have tended to drift downward, though this tendency is neither pronounced nor universal.

A variety of reasons exists for setting the transfer charge at a particular level. In approximate order of importance for the properties participating in this study, these include the following:

- Historical precedent: Many properties have not recently given serious consideration to the level of their transfer charge;
- Transfer abuse: A nonzero transfer charge may reduce the "resale" of transfers at a price below that of a full fare or the giving away of the transfers to friends and relatives, since fewer people would take transfers with the intent of later distribution if they had to pay something for them; and

- Political/equity: A particular transfer charge may be justified on the basis of a desire not to penalize transfers, not to subsidize long trips, etc.

Revenue, public relations, bus running times, and other considerations may also affect the selection of the transfer charge. The cost consequences of a particular transfer charge result from the possible slowdown in bus passenger entrance and the minor cost of counting and handling additional revenue. The cost of slowing down the bus to process the transfer charge may be significant, and results from both the need to pay a charge and from disputes that may develop between drivers and passengers over transfer abuse.

User satisfaction is decreased as the transfer charge goes up since, by definition, individuals are made worse off by extra cash expenditures. The magnitude of this effect is determined by the disutility associated with charges by different user groups, and the "justifiability" of the charge (i.e., the feeling among riders that the charge is fair and has a purpose, such as to make longer trips cost more).

Both total bus ridership and the bus/bus transfer rate appear to be sensitive to the level of transfer charge. Different types of riders and trips will be affected differently by a change in transfer charge. Captive riders have their riding patterns altered least by an increase in transfer charge, while shopping and other discretionary trips would be most discouraged. These ridership changes translate directly into effects on revenue. Because of the generally inelastic demand for transit, total revenue will typically increase (sometimes by a substantial amount) as the transfer charge goes up.

Overall, each of the three levels of transfer charge -- zero, small but nonzero, and full -- seem to be stable and viable. The selection of one over the others is based on the operator's priorities and various other site-specific factors.

Rail Transfers

Rail transfer charges are considerably less uniform across different properties than bus transfer charges. There are full-fare transfers, half-fare transfers, dime transfers, nickel transfers, and free transfers. Rail/rail transfers tend to be free, though this is not always the case. The principal reasons for setting the rail transfer charge at a particular level include (in approximate order of importance):

- Historical/institutional/political: Past and present relationships among bus and rail operating authorities may be big factors in determining the transfer charge;
- Revenue: This may be particularly important for properties with large operating deficits;
- Abuse: Rail transfer systems that depend on automatic dispensers in rail systems are particularly susceptible to abuse;
- Equity: Depends on local priorities; and
- Facility design: This may produce "logical" transfer charges (e.g., zero charge for across-platform transfers).

The only direct cost consequences that result from the rail transfer charge are the minor costs associated with processing revenue. (There may be significant costs associated with the transfer slip method used but these are treated in the next section.) The demand-side consequences of a particular rail transfer charge are basically the same as those for bus transfer charges. User satisfaction must go down as the transfer charge goes up, with the amount of change depending on sensitivity of different user groups and the degree of "justifiability" of the transfer charge. Since rail transfers may consist largely of fare-inelastic work trips, and tend to be part of longer trips than bus transfers, rail transfer charge increases may decrease user satisfaction less than corresponding changes in the bus transfer charge would.

Transfer Slips

Bus Transfers

Transfer slips are the principal method for offering reduced fare bus transfers, entitling riders to board subsequent vehicles at a reduced fare. Most properties use conventional transfer slips, but some use daily passes or even no transfer slips at all to grant reduced fare transfers.

The cost of administration of transfer slips is low. User satisfaction, ridership, and revenue consequences of transfer slips follow primarily from their use in setting fare policy, and not from any characteristic intrinsic to the transfer slips themselves.

Rail Transfers

A variety of methods are available for offering reduced charge rail transfers. These include:

- Transfer slip issued by bus driver or change booth clerk, collected by same;
- Commuter rail pass good on transit;
- Two-part rail pass issued on train or in station, one part good for bus trip away from rail and other part good for bus trip toward rail;
- Transfer to bus dispensed from machine in rail station at destination;
- Transfer to bus dispensed from machine at originating rail station;
- Direct paid area for bus/rail transfers;
- Magnetic card for transfer to rail obtained on bus; and
- Rail-to-bus transfer obtained from original bus driver.

In contrast to bus transfer slips, these methods for providing rail transfers generally have significant cost consequences. Rail stations must handle large volumes of

passengers. Since ordinary bus transfer slips must be accepted by a person for validity checks, a mere extension of bus transfer procedures to transfers will not work without extra labor cost. Other potential costs include the transfer slips themselves (estimated to be $225,000 per year in Boston), the transfer-dispensing machines (where used), and the extra cost of station construction when a paid area is included.

The method of providing rail transfers has a significant indirect effect on user satisfaction, ridership, and revenue because of the constraints that it places on the level of transfer charge. User satisfaction is also affected if the transfer slip procedure requires the passenger transferring from bus to rail to wait in a long line instead of going directly through the turnstiles. In this case, the rider is faced with the choice of not getting a transfer or waiting in line, necessarily reducing user satisfaction.

The method of offering reduced fare transfers can in addition affect the amount of abuse which occurs, and hence revenue which is received, even after factoring out the effects of the transfer charge. Transfers issued by machine (especially in the destination station) tend to be more easily abused (with consequent revenue losses), because many extra transfer slips can be taken by an individual. Various strategies for locating the transfer machines can be tried to alleviate this problem, but it is inherent in the nature of the automated transfer slip distribution system.

Overall, there appear to be many viable methods for offering reduced-fare rail transfers. None of them, however, are flawless. Thus, for most transit systems, there is no dominant method of transfer administration.

Schedule Information

The provision of schedule information is an option of broad general interest in transit. Schedule information useful for transferring can be provided either at the transfer point or prior to the start of the transit trip. At the transfer point, transit properties can supply or post printed schedules or maps, and/or disseminate information about whether the connecting vehicle is late. Prior to the trip, sources of information include printed schedules (which may include information on transfer points, time points, and "best connecting vehicles"), and telephone information systems. Schedules can also provide information on the other components of the transfer policy (e.g., through-routing, dynamic control, schedule coordination, timed transfers). In general, most properties only indicate the transfer charge and procedure for transferring on their schedule, and almost never indicate the use of dynamic control or schedule coordination.

The direct costs of providing schedule information include printing schedules, manning phone banks, etc. The indirect costs are a type of opportunity cost, which occurs when a operator publicly states a transfer policy, and then feels committed to it even when it becomes unproductive to do so. Provision of schedule informatin at the transfer point may raise the satisfaction of the rider by limiting his uncertainty, and by freeing him for other productive activities (which may be equivalent to a significant reduction fo transfer wait time). Awareness of schedule information prior to the start of a trip will raise user satisfaction by enabling the passenger to make beneficial changes in trip-making behavior.

If the schedule and routes of a transit system never changed, provision of schedule information of all types would almost universally be the preferred action. However, transit routes and schedules frequently change (typically) requiring an

information/cost tradeoff to be made. Each operator must determine whether the benefits produced by providing information about a particular transfer policy component are offset by direct costs, and the need to make periodic adjustments in schedules and routes.

Marketing

Transfer-related marketing initiatives by the transit operator can focus completely on transfers, be part of a broader marketing effort, or use transfers to market other aspects of the transit system. When the transfer policy has some important distinguishing feature which can potentially affect a significant number of riders (e.g., pulse scheduling, universal transfer valid between carriers), it can be the focal point of a marketing effort. In addition, it is possible to market "responsiveness" by such means as a limited use of schedule coordination in which individual runs are adjusted to promote user satisfaction in response to user complaints.

Many properties promote transfers as part of broader marketing efforts. For instance, properties often produce brochures describing their special services, including brochures on how to transfer. Transit fare prepayment plans are another important example of the marketing of transfers as part of a larger effort, since the transferring rider usually receives free transfers.

Transfer slips can also be used as part of marketing efforts that have nothing to do with transfers, such as the use of transfer slips as daily passes, or special promotions in which retail establishments offer their customers return fares in exchange for transfer slips.

The cost of transfer-related marketing can be low, especially if there are few transfer points. The user satisfaction consequences of marketing are related to the changes it can cause in awareness of and attitudes toward

transit. Transfer-related marketing can change people's perceptions that transfers are onerous by promoting aspects of the transfer policy which make transfers easier. Marketing has been used to raise the awareness of different market segments concerning the existence of various transfer policy components, as well as coverage and services provided by the system as a whole. It remains uncertain, however, whether marketing <u>directed specifically toward transfers</u> on properties whose transfer system has no special attributes is appropriate or productive.

Conclusions

Each of the 11 transfer policy components described can be cost-effective in various situations. The decision to utilize a particular policy component must address the tradeoffs among that component's various consequences. For instance, the introduction of a transfer fee on a property where there were previously free transfers involves balancing equity, revenue, and user satisfaction considerations. Tradeoffs of this type are important from the point of view of the operator in determining how well a particular transfer policy meets system goals and objectives. It is important to note that combinations of transfer policy components may produce consequences that are not simply additive. For example, instituting timed transfers will, in general, have a positive effect on user satisfaciton, as will increasing schedule reliability. However, the magnitude of the consequences of timed transfers will usually depend on the reliability of the connection, which involves increased schedule reliability. Hence, the increases in user satisfaction caused by implementing timed transfers and increasing schedule reliability may exceed the sum of the benefits derived from

using those two components individually. Furthermore, some options have more widespread applicability than others; through-routing, for instance, can probably be implemented on a wider range of property types than pulse scheduling, although pulse scheduling has more far-reaching effects. Each operator must evaluate the service, cost, and demand conditions on the property and the consequences of alternative policies to determine which actions would be the most productive.

Chapter 1
INTRODUCTION

1.1 Introduction

This study investigates the cost, ridership, revenue, and user satisfaction consequences of alternative transit transfer policies. A transfer policy consists of a set of operator actions involving vehicle routing and scheduling, transfer charges, and information for passengers which, in some way, affects the movement of passengers between transit vehicles as part of a continuing trip. Under ideal circumstances, transit would carry all users directly from their origins to their destinations without requiring a change of vehicles. However, given the dispersed geographic and temporal distribution of trips, such direct service is, of course, uneconomical for transit to provide. Therefore, operators must take some set of actions (a "transfer policy") to serve transferring passengers.

As specific transfer policy options are implemented, the costs of providing service will vary. Also, as the characteristics of the service change from the consumers' viewpoint, there will be differences in the level of

satisfaction obtained by transferring and nontransferring passengers alike. These may lead to changes in ridership and revenue. The purpose of collecting and analyzing data on current and recent transfer policy practice is to enable evaluation of potential transfer policies on the basis of their expected costs and benefits.

1.2 Conduct of the Study

The results of this study are based primarily on information collected in telephone interviews with transit professionals knowledgeable about current or recent transfer practice in the United States. Discussions were carried out with a total of 39 transit operating authorities in 37 cities. The cities contacted encompassed both bus and rail transfer policies. Rail transfer policies apply to transfers between bus and (heavy or commuter[1]) rail or rail and rail. Bus transfer policies apply solely to transfers between buses. Figure 1-1 lists the properties which contributed information to the study of bus transfer policies. (Since some authorities manage more than one transit system, the actual number of cities whose experience is incorporated in this report is higher than the number of transit authorities contacted. The additional cities are listed in parentheses in Figure 1-1.) Figure 1-2 lists the corresponding rail properties which contributed information to the study. Some properties are

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[1]Transfers involving light rail have explicity not been included in this study. The characteristics of light rail operations (e.g., use of shared or reserved right-of-way, at grade or grade separation, platform facilities/stations, etc.) vary widely across settings, making it extremely difficult to draw useful generalizations.

Figure 1-1

PROPERTIES PARTICIPATING IN THE BUS TRANSFER POLICY STUDY

Albany, NY
Atlanta, GA
Baltimore, MD
Boston, MA
Brockton, MA
Buffalo, NY
Charleston, WV
Cleveland, OH
Columbus, OH
Denver, CO
Duluth, MN (Superior, WI)
Eugene, OR
Everett, WA
Fresno, CA
Greenfield, MA
Hartford, CT
Indianapolis, IN
Jacksonville, FL
Knoxville, TN
Lafayette, IN
Lawrence, MA (Haverhill, MA)
Lewiston, ME
Memphis, TN
New York City, NY
Pittsburgh, PA
Portland, ME
Portland, OR
Providence, RI
San Francisco, CA[1]
Springfield, MA[2]
Toledo, OH
Washington, DC
Westport, CT
Winston-Salem, NC

[1]San Francisco Municipal Railway.
[2]Pioneer Valley Transit Authority.

Figure 1-2

PROPERTIES PARTICIPATING IN THE RAIL TRANSFER POLICY STUDY

Atlanta, GA
Boston, MA
Chicago, IL
Cleveland, OH
Detroit, MI[1]
New York City, NY
Philadelphia, PA
Pittsburgh, PA
San Francisco, CA[2]
Westport, CT

[1]Southeastern Michigan Transportation Authority (SEMTA).
[2]San Francisco Municipal Railway, Bay Area Rapid Transit, and Alameda-Contra Transit.

found on both lists, indicating their contribution to analysis of both bus and rail transfer policies.

The properties in Figure 1-1 were selected as the result of a well-defined process of identifying candidates for productive discussions. (Due to the small number of properties with rail rapid transit operations, the list in Figure 1-2 includes almost all properties with rail transit, as well as some commuter rail.) The selection process for the study of bus transfer policies began by identifying cities with innovative or interesting transfer policies. This listing was then augmented by including properties which would be likely to cooperate with the study (e.g., if operators were acquaintances of study team members). Segmentation criteria were developed (see Figure 1-3) to ensure that the study examined properties with many kinds of policies and attitudes in a variety of environments. The final selection of approximately 30 properties for bus transfer policy interviews attempted to draw evenly from the 12 cells of the segmentation scheme in Figure 1-3.

Figure 1-4 shows the properties eventually selected for bus transfer policy interviews, and their place in the segmentation scheme. Note that some cells are empty or nearly so. Ideally, each cell would have contained approximately the same number of properties. However, some cells (e.g., full-fare transfer charge) are very sparse in practice, possibly reflecting empirical relationships between the segmentation characteristics.

The interviews themselves generated primarily qualitative data linking specific transfer policies to their consequences. In addition, a limited amount of site-specific quantitative data were obtained from some properties. In general, formal "before-and-after" studies of changes in transfer policies <u>only</u> have not been performed and are not available. Rather,

Figure 1-3

SEGMENTATION CRITERIA FOR THE BUS TRANSFER POLICY STUDY

Criterion	Value	Definition
Population of service area	Large	Over 600,000
	Small	Under 600,000
Amount of transfer charge	Zero	$.00
	Reduced	$.05, $.10
	Full-fare	Base fare
Extensive use of timed transfers	Yes	Many routes involved during day
	No	Most routes not involved during day

Figure 1-4

SEGMENTED PROPERTIES FOR BUS TRANSFER POLICY STUDY

Properties Which Do Not Use Timed Transfers Extensively

Transfer Charge	Small Size	Large Size
Full	Lawrence, MA Jacksonville, FL	Boston, MA
Reduced	Springfield, MA Toledo, OH[1] Winston-Salem, NC Knoxville, TN[1] Providence, RI	Pittsburgh, PA Memphis, TN[1] New York City, NY Baltimore, MD Buffalo, NY Indianapolis, IN
Zero	Portland, ME Hartford, CT Greenfield, MA Charleston, WV Duluth, MN	Washington, D.C Columbus, OH[1] Cleveland, OH[1] Atlanta, GA San Francisco, CA (Muni) Albany, NY[1]

Properties Which Use Timed Transfers Extensively

Transfer Charge	Small Size	Large Size
Full		
Reduced	Lafayette, IN	
Zero	Westport, CT Eugene, OR Fresno, CA Brockton, MA (Haverhill, MA) Lewiston, ME (Superior, WI) Everett, WA	Denver, CO[2] Portland, OR[2]

[1]Use timed transfers in evenings ("line-ups").
[2]Planning but not currently using timed transfers extensively.

SOURCE: Charles River Associates Incorporated, May 1979.

respondents were encouraged to draw on their experience and offer information and insights concerning the consequences of particular transfer policies in different settings.

Sophisticated statistical methods were not used on the data collected in the study. It was more appropriate to tabulate the characteristics of existing transfer policy applications and compare the effects of the same transfer policy component at different properties. This analysis procedure yields qualitative relationships among transfer policy components, their consequences, and site-specific factors which indicate the general magnitude and direction of the changes that can be expected if a transfer policy is modified in a particular situation. These results should provide a valuable guide for transit operators interested in the consequences of implementation of particular transfer policies on their system.

1.3 Outline of the State-of-the-Art Report

Chapters 1 through 3 of this report describe the available transfer policy options addressed in this study, and provide a detailed description of the study approach. Chapter 4 describes findings on the characteristics of transferring passengers. Subsequent chapters describe and analyze the current practices and consequences associated with each of 11 individual transfer policy "components" (see Chapter 2). Each component has its own chapter, and each chapter is divided into five sections.

The first section of each chapter is a summary description of the transfer policy component and its applicability. The second section is an in-depth review of current practice for the component when applied as part of a bus/bus transfer

policy. This section includes the operator actions required to implement the component, the types of transit properties at which the component can be found, and how the use of the component varies from property to property. The third section in each chapter describes current practice for that component when applied as part of a bus/rail or rail/rail transfer policy.

The fourth section of each chapter analyzes the cost, user satisfaction, ridership, and revenue consequences which follow from the use of that policy component. This section utilizes available quantitative and qualitative information obtained from both users and nonusers of the component concerning the effects each component would have. Whenever appropriate, the differences in consequences between application of the component in bus and rail settings are detailed. Finally, the fifth section provides a synthesis of the findings. The end result is that relationships are suggested between the consequences of the policy component and such site-specific factors as historical and current patterns of passenger flows, route structure, shape and size of the service area, layout of the CBD, existing transfer charges, and degree of schedule adherence.

The last chapter is a summary of the conclusions which can be made in both a general and a site-specific sense about transfer policies and their consequences. In addition, the role of transfer policy changes in the context of overall system modifications is addressed.

Chapter 2
BACKGROUND

2.1 Transit Transfer Policy Options and Impacts

The opportunity for passengers to "transfer" as part of a transit trip has existed for well over a century. Ever since the time two or more transit routes converged or crossed one another, transit transferring has been possible. The early positive character of transfers that existed when public transportation had a virtual monopoly on urban vehicular transportation has unfortunately given way to today's negatively valued "need to transfer" as part of current public transit operation.

Today's urban areas are characterized by widely dispersed travel demands in space and time. Public transit involves aggregating or collecting people in space and time and transporting them in "packages" or groups on transit vehicles. Such transit service cannot serve as a perfect link between all origins and destinations at the times when such trips are desired. Direct service involving no change of vehicle also

cannot be provided between all parts of a region actually served by transit, thus requiring passengers to transfer between vehicles.

Even on the smallest systems, transit agencies have a policy regarding transfers. The policy may be explicit in that it delineates vehicle routing, schedules, and fares pertaining to transfers, or it may be silent so that passengers must pay a full fare and take their chances on waiting up to the full headway when transferring to another route. In either case, the policy for accommodating transfers is based on a set of goals and objectives (explicit or implicit), and represents the selection of a program of action (or inaction) over many other alternatives.

2.2 Transfer Policy Components

Given the large number of possible combinations of transfer-related actions, and the variety of scenarios in which each might be implemented, it is clear that the task of identifying the supply and demand effects of a particular transfer policy is quite formidable. The principal method for making this task manageable is the reduction of transfer policies into components. Transfer policy components (also known as transfer policy options or elements) are the basic building blocks which make up transfer policies, and are thus both less numerous and less complex to study than composite transfer policies.

Eleven transfer policy components will be explored in this study. These are the following:

A. Routing Components

1. Distance between routes at transfer points;
2. Through-routing;

B. Scheduling Components

3. Schedule coordination;
4. Dynamic control of departure times at transfer points;
5. Timed transfers;
6. Schedule adherence on connecting routes;
7. Service frequency on connecting routes;

C. Pricing Components

8. Transfer charge;
9. Use of transfer slips;

D. Information Components

10. Provision of schedule information;
11. Marketing initiatives.

As indicated by the four subheadings, grouping these options into categories helps clarify their interrelationships. For example, distance between vehicles at transfer points and through-routing are both principally concerned with spatial placement of routes and walking distances for transferring passengers. The first transfer policy option (distance between routes at transfer points) is the most basic option of this type, and includes changes in bus routing at the transfer point and design of rail station facilities. Through-routing (the second option) presumes that routes are physically aligned in a manner which facilitates the interlining of vehicles (i.e., have adjacent termini) and additionally requires that schedules be made compatible, since frequencies normally must match on connected routes.

The second category of transfer options is primarily concerned with the timing of vehicle movements (i.e., scheduling). The goal of these transfer policy components is generally to provide low transfer times between routes while at the same time not adding significantly to operating costs and

the inconvenience of nontransferring passengers. Under the first of the five options in this category (schedule coordination), the arrival of vehicles at a transfer point is scheduled to minimize the wait time of transferring passengers without necessarily guaranteeing a physical meeting of vehicles. The next component, dynamic control of departure times at transfer points, provides for vehicles to be held and meet other vehicles on connecting routes whenever the disruptive effects on the system are not excessively large. Timed transfers represent the extreme component of this type, since it virtually guarantees that vehicles will actually meet at the transfer point through revision of schedules (and possibly routes).

Each of the remaining two scheduling options has impacts which go well beyond the subject of transfer policy design. However, to the extent that they impact transfer policy, it is important that they be addressed. Improved schedule adherence seeks to maximize the reliability of currently scheduled vehicles, and to reduce the mean and variance of wait time for transferring passengers. Increased service frequency (i.e., scheduling more service) is also likely to reduce wait time for transferring passengers, and ultimately to reduce the need for any kind of schedule coordination between transferring vehicles.

The third category of transfer options relates to pricing and financial considerations. Obviously, the transfer charge itself is the most important option of this type. However, the method of administering the charge (e.g., use of transfer slips or provision of a gate-free paid area for transfers between bus and rail) has its own impacts which must be accounted for when free or reduced fare transfers are to be provided.

The fourth and last category consists of options primarily concerned with the dissemination of transfer information. The basic option of this type is the provision of schedule information about existing services. More aggressive marketing initiatives may not only increase the level of factual understanding of system operations, but also change users' overall perceptions of transit.

These transfer policy components do not exhaust the list of possible actions with which a study of transfer policies might be concerned. It should be noted that there are other transfer policy components such as transit shelters, terminal facilities, and temporal and directional restrictions on reduced fare transfers which affect transferring passengers. Due to budget limitations, however, these are explicitly omitted from this study. Thus, the present study concerns itself only with the 11 transfer policy components listed above.

2.3 Transfer Policy Consequences

By definition, implementation of a particular transfer policy by an operator involves a set of actions which are likely to have important consequences on both the supply side and demand side. These consequences can usefully be categorized as effects on operator costs, user satisfaction, ridership, and revenue.

The operator costs relevant to evaluating alternative transfer policy components are composed of several different elements. First, of course, are actual vehicle operating costs, as measured both by unit cost of vehicle operations (e.g., cost per vehicle mile) and as measured by volume of vehicle operation (e.g., vehicle miles operated). Second, some transfer policies have administrative or overhead costs

associated with them which do not vary markedly with volume of vehicle operations. Third, capital costs can be affected by the choice of transfer policies.

User satisfaction depends on the transfer level of service. Attributes of this level of service are listed in Figure 2-1. Any change in transfer policy will affect, either directly or indirectly, one or more of these attributes, which in turn will affect the satisfaction of users from different market segments to different degrees.

The changes in user satisfaction produced by alternative transfer policies will usually lead to ridership changes as well. The changes in ridership are of two types. First, changes in total transit trips (i.e., attraction of additional person-trips to system) and second, changes in unlinked trips without changes in total trips (i.e., inducement of transit users to transfer more).

It is important to note that the change in transfer level of service with a given transfer policy may vary by market segment due to different spatial distribution of activities. In addition, a particular change in transfer level of service may not lead to identical changes in transit use for different user groups. For example, riders with an auto available will differ from "captive" riders, who have no other choice and may continue to use transit regardless of the quality of service (although their frequency of use and trip length may vary).

Finally, any ridership changes which do occur will generally lead to revenue impacts as well. The magnitude of the changes in revenue will depend on the relevant fares and transfer charges. The amount of revenue associated with a transfer policy can also vary depending on the level of abuse of the transfer fare collection procedures.

Figure 2-1

TRANSFER LEVEL OF SERVICE ATTRIBUTES

<u>Considered in Study</u>

- Walking time/distance required to transfer (horizontal distance or vertical distance)
- Transfer versus no transfer (i.e., by through-routing vehicles)
- Average wait time for connecting vehicle
- Variance in wait time (transfer reliability and probability of making connection)
- Transfer charge (pricing transfers equal to or less than full fare)
- Ease of comprehension of transfer policy (for above attributes)

<u>Not Considered in Study</u>

- Temporal and directional limitations on nonfull fare transfers
- Transfer amenities (e.g., shelter from elements, physical security)

An additional consequence which is external to the system, and hence does not fall into the above categories concerns political/equity issues. Equity considerations can be important if a transfer policy affects one user group more than another. Political feasibility (e.g., constraints on the distribution of transit services caused by system financing arrangements) often determines what transfer policies can be implemented.

Special attention will be paid in this report to the tradeoffs between different consequences of a transfer policy. For instance, the introduction of a transfer fee on a property where there were previously free transfers involves balancing equity, revenue, and user satisfaction. Tradeoffs of this type are important from the point of view of the operator in determining how well a particular transfer policy meets relevant goals and objectives.

A final key issue to be considered is the combination of transfer policy components into transfer policies. The transfer policy component is the primary unit of analysis in this study. However, combinations of components whose consequences are not simply additive will be identified to the greatest extent possible. For instance, instituting timed transfers will in general have a positive effect on user satisfaction, as will increasing schedule reliability. However, the magnitude of the consequences of timed transfers will usually depend on the reliability of the connection, which involves increased schedule reliability. Hence, the increase in user satisfaction from the two components used together may not simply be the sum of the two components used individually. Thus, an important focus of this report will be the identification of cases where there are large interactional effects among transfer policy components.

Chapter 3
STUDY APPROACH

3.1 Introduction

The basic approach to this study has been to collect data on alternative transfer policies and their impacts by means of extensive telephone interviews with knowledgeable transit professionals at a variety of transit properties across the country. The large amount of information gathered from these interviews was then analyzed to determine the effects of changes in a transfer policy.

Section 1.3 has already outlined the properties at which interviews were conducted, and the criteria used in choosing these properties. The next section (Section 3.2) describes the types of people interviewed, the types of data collected, and the manner in which the data were analyzed. Finally, Section 3.3 lists the conditions and caveats which are important for understanding the limitations of the scope of this study and the validity of the results obtained.

3.2 Selection of Properties

The selection of the properties at which interviews were to be conducted for the study of bus transfer policies involved several steps. The first step involved a review of available literature to provide an introduction to the transfer practices of many transit properties. Particular attention was given to local cities which have undertaken noteworthy initiatives in the transfer area, since operators in these cities would appear to be good interview prospects. This list of properties was augmented by including acquaintances of study team members who were likely to be cooperative with the interviewing process.

The next step was to formulate segmentation criteria to ensure that the properties at which interviews were conducted encompassed a wide variety of environments, attitudes, and policies for transfers. In this manner, self-perpetuating biases in favor of the most prevalent current policies could be minimized while the merits of less popular approaches could be evaluated for potential future applicability.

The following three dimensions were used in the "segmentation" of properties.

- Population of service area. Though definitions of service area vary between localities, this measure was used as a proxy for the congestion and demand levels experienced by the system. These factors, in turn, have a direct impact on operational characteristics, such as schedule reliability, which influence the applicability of different options (particularly timed transfers). Properties were divided into two groups: large (service area population greater than 600,000) and small (less than 600,000).

- Transfer charge. The inclusion in the study of properties which employ a complete range of transfer charges (zero, reduced, or full-fare) was especially important. Aside from the potential system-based consequences of alternative transfer charges, there are "philosophical" differences which may underlie the willingness of operators to pursue different fare policies. By explicitly considering a range of transfer charge options, it was possible to include properties which have fundamentally different attitudes toward their passengers and different priorities in service design.
- Extensive use of timed transfers. Obviously there is merit to questioning users and nonusers of an option as significant as timed transfers. In addition, given the complexity of the changes which can accompany "pulse" scheduling, it was hypothesized that operators who employ this option perceive transfers to be a major issue, and are willing to devote a high level of effort to improving them. Thus, users of this option were likely to be productive respondents.

Figure 3-1 lists the segmentation characteristics of each property where interviews were conducted for the study of bus transfer policies.

One criterion for selection which was included only informally, but was nevertheless important, is geographic location. It is possible that regional differences in the applicability of different transfer policy options will be significant. For example, older cities in the northeast may have evolved around relatively dense central business districts, while more recently developed western cities exhibit more dispersed land-use patterns. Given the importance of congestion and demand levels described earlier, and the relationship between these factors and density, the relevance

Figure 3-1

SEGMENTATION CHARACTERISTICS,
BUS TRANSFER POLICIES

Property	Population in Service Area (Thousands)	Transfer Charge (Cents)	Base Fare (Cents)	Extensive Use of Timed Transfers	Comment
Albany	720	0	40	No	Uses line-up at night
Atlanta	1680	0	15	No	
Baltimore	1750	5	30	No	
Boston	2760	25	25	No	
Brockton	100	0	25	Yes	
Buffalo	1340	5	40	No	
Charleston	200	0	25	No	
Cleveland	1800	0	25	No	Has line-up at night
Columbus	1050	0	50	No	Has line-up at night
Denver	1540	0	50	Yes	Neighborhood pulse planned
Duluth	140	0	35	No	Uses pulse in Superior, WI
Eugene	210	0	35	Yes	
Everett	50	0	20	Yes	
Fresno	310	0	25	Yes	
Greenfield	70	0	25	No	
Hartford	470	0	35	No	
Indianapolis	790	5	50	No	
Jacksonville	580	25	25	No	
Knoxville	190	5	30	No	Has line-up at night
Lafayette	110	5	25	Yes	
Lawrence	200	30	30	No	Uses pulse in Haverhill, MA
Lewiston	70	0	30	Yes	
Memphis	670	5	50	No	
New York City	8000	25	50	No	
Pittsburgh	1600	10	50	No	
Portland, ME	106	0	35	No	
Portland, OR	950	0	40	Yes	Neighborhood pulse planned Also has pulse at night
Providence	600	5	35	No	Uses pulse in Pawtucket, RI
San Francisco	670	0	25	No	
Springfield, MA	500	10	--	No	
Toledo	500	5	35	No	Has line-up at night
Washington	2500	0	40	No	
Westport	30	0	50	Yes	
Winston-Salem	150	5	35	No	

SOURCE: Service Populations; *APTA Membership Directory - 1978*; *APTA Membership Directory - 1979*; *APTA Transit Operating Report - 1975*; and *APTA Transit Operating Report - 1976*. Fare and timed transfer information (as of March 1979); operator interviews.

of geographic descriptors is clear. Also, it is important for this study to avoid regional biases in order to preserve the credibility of its results with transit operators throughout the country. Therefore, the properties at which interviews were conducted were drawn from the widest possible geographic distribution.

For the next step in the selection process, it was necessary to ensure that the segmentation data were accurate, and that appropriate interviewees were available. Therefore initial phone calls were placed to individuals at approximately 60 properties in order to obtain or verify basic data on the transfer charge, use of timed transfers, and use of through-routing. These phone calls, which were typically made to individuals in public relations/marketing positions, also yielded schedules, route maps, and internal analyses which were helpful in the course of this study.

As much as possible, the properties at which interviews were to be conducted were to be spaced evenly across the 12 cells in the segmentation scheme to obtain the desired successful interviews at approximately 30 properties. However, 7 out of the 12 cells -- notably those with a full transfer charge -- proved very difficult to fill (see Figure 1-1). The difficulty in filling all segmentation cells can be attributed to the types of transfer policies currently in use, and is discussed in detail in later chapters.

The same multistep selection process was not necessary to choose the properties to interview regarding rail transfer policies. Given the comparatively small number of properties with rail rapid transit, the decision was made to interview almost all of them, as well as some cities served by commuter rail. Figure 3-2 lists the applicable segmentation characteristics (size and transfer charge) of the properties

Figure 3-2

SEGMENTATION CHARACTERISTICS, RAIL TRANSFER POLICIES

Urban Area	Population in Service Area (Thousands)	Predominant Bus/Rail Transfer Charge (Cents)	Predominant Rail/Rail Transfer Charge (Cents)	Base Fare (Cents)	Comments
Atlanta	1680	0	0	25	
Boston	2760	25	0	25	Commuter rail-to-rail transit free with pass.
Chicago	4000	10	0	50	
Cleveland	1800	10	0	25 (bus)	Transfer charge only applies from local bus to rail.
Detroit	2500	0	NA	NA	Between commuter rail and feeder bus.
New York	8000	50	0	50	Bus/rail transfers free where bus has replaced rail transit.
Philadelphia	4000	5	5	45	Transfer charge $.30 between divisions. Wide range of reduced fares between commuter rail and feeder bus. Transfers from Lindenwold line are half fare.
Pittsburgh	1600	10	10	50	Transfer to commuter rail is full fare.

Table continued on following page.

Figure 3-2 (Continued)

SEGMENTATION CHARACTERISTICS, RAIL TRANSFER POLICIES

Urban Area	Population in Service Area (Thousands)	Predominant Bus/Rail Transfer Charge (Cents)	Predominant Rail/Rail Transfer Charge (Cents)	Base Fare (Cents)	Comments
San Francisco	2354	Half-fare	0	25	Transfer between BART and Muni or AC Transit.
Washington, DC	2500	Half-fare	0	40	
Westport	30	Full	NA	50	Transfer between Conrail and Westport buses.

interviewed regarding rail transfer policies, though these characteristics were not used to select the properties to be interviewed.

3.3 Interview Process

In the course of the interview process, approximately 70 different people were interviewed. These included general managers, schedule makers, operations planners, marketing personnel, and others. Note that at many properties, more than one individual was interviewed. Also, many individuals were interviewed more than once.

The interviews addressed the following topics:

- Detailed characteristics of current transfer policy;
- Rationale for current transfer;
- Consequences of current transfer policy;
- Past practices and results of changing transfer policies;
- Alternatives considered and anticipated impacts; and
- Advantages and disadvantages of different transfer policies.

Some site-specific quantitative data relevant to changes in transfer policies were obtained from the interviews. Unfortunately, almost none of the data corresponded to careful "before-and-after" studies of changes in transfer policy only. Such disciplined evaluations currently characteristic of the Service and Methods Demonstration Program have been essentially nonexistent in the transfer policy area. The interviews did provide a large amount of qualitative data linking specific transfer policies to their consequences. In addition, many of the respondents, drawing on their experience in transit, were able to offer informed opinions concerning the types of properties where particular transfer policies would be

applicable, and what their consequences would be. This highly insightful though generally qualitative information is presented in this report.

The chosen method of analysis has been to tabulate the characteristics of existing transfer policy applications in order to link components of transfer policies with their consequences. This analysis proceeded concurrently with the data collection, enabling the formation of tentative hypotheses which could be discussed during subsequent interviews. The information collected in the study was generally too qualitative to warrant the use of sophisticated statistical models.

By comparing the effects of the same transfer policy component at different properties, it has been possible in many cases to infer how the relationships between transfer policy components and their consequences are influenced by site-specific factors. It should be emphasized that these relationships are not in equation form. Rather, they are indications of the general magnitude and direction of change that can be expected if a transfer policy is changed in a particular situation. These qualitative relationships are quite easy to use, particularly for people without the time or resources to employ sophisticated models.

3.4 Qualifications and Caveats

Having described what this study was designed to do, it is equally important to discuss relevant limitations on study findings. These caveats are essential for understanding the significance of study results.

One group of caveats concerns limitations set on the scope of the study before it was begun:

1. Temporal and directional restrictions on reduced-fare transfers are not considered.
2. Transfer amenities, such as shelters from the elements and physical security, are not considered.
3. Detailed rail station layout and bus terminal layout will not be considered.
5. Route structure is generally assumed to be fixed, as are other site-specific characteristics of the transit properties except where otherwise mentioned.

A second set of limitations on the study results are those imposed by the study approach and the nature of the available data:

1. Data, and hence conclusions, are generally qualitative and not quantitative in nature.
2. The study was not designed to be a statistically random survey of transfer policies. The properties at which interviews were conducted were chosen, in part, because they had interesting transfer policies, or available data, and were cooperative with the study. Hence, this study cannot make reliable statements concerning the current overall utilization of particular transfer options.
3. In the sample of properties at which interviews were conducted some bias may exist toward publicly owned properties, who are members of APTA and whose executive staff are active in the Transportation Research Board (TRB).
4. Since changes in transfer policy usually occur simultaneously with other major system changes, it is difficult to separate out the transfer-related effects from the other effects.
5. Interviews, by nature, yield a subjective view of the consequences of transfer policies. This is especially true for user satisfaction, for which serious measurement problems exist under the best of circumstances.

6. Interviews with more than one individual at the same property often reveal differing appraisals of a particular transfer policy. For example, on properties where a formerly private operator is now under a transit authority, the views of the planners at the authority and the operators often diverge.
7. Some highly useful quantitative data, particularly transfer rates, have been made difficult to collect by widespread use of prepaid passes, free-fare zones, and through-riding.

These limitations place some restrictions on the robustness and generalizability of study findings. Within these limitations, however, it has been possible to arrive at conclusions which should aid operators in formulating and evaluating transfer policies for their properties.

3.5 Literature Review

A review of literature relevant to transfers and transfer policy design was conducted at the beginning of the study. This literature review had several purposes:

- Review of findings of previous studies of transfer policy issues;
- Development of research issues;
- Selection of transit properties for interviewing; and
- Review of relevant transit demand studies.

Unfortunately, previous research on transit transfers has not generally addressed many of the substantive issues in the current study. There are very few cases where rigorous analyses of transfer policy alternatives have been undertaken. Previously documented quantitative work at the local level tends to consider many service improvement recommendations simultaneously, without distinguishing between the impacts caused by the change in transfer policy and those which could be attributed to other changes.

For example, although many transit agencies have data on changes in transit ridership that occurred after changes in fares, there is a paucity of published data on changes in transit ridership that can be attributed solely to changes in transfer charges. Since a change in transfer charge is usually associated with a change in system-wide base fares, it is difficult to distinguish the separate effects of each change. For this transfer component, as well as the others, the literature review yielded little direct information on the consequences of different transfer policies.

However, the literature review was helpful in determining many important topics which needed to be addressed in the operator interviews. For instance, the Transportation Systems Center (TSC) staff study on timed transfers[1] raised several important points about their consequences and applicability. The Providence Auto Restricted Zone (ARZ) study[2] identified some considerations relevant to through-routing and transfer pricing. Issues related to a limited number of other transfer options were also addressed in the literature.

The literature review provided considerable guidance in selecting the properties to be interviewed. American Public Transit Association (APTA) Fare Reports and Operating Reports yielded information on transfer charges and number of transferees. Trade periodicals were another good source of "interesting" transfer policies to be studied. Taking all of

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[1]K. H. Schaeffer, "Timed Transfer Focal Point Service," Transportation Systems Center, November 1976.

[2]Alan M. Voorhees and Associates, Providence Auto Restricted Zone Technical Appendices, UMTA, June 1977.

the available information into account, it was possible to isolate a productive set of sample properties with relevant transfer policies.

The fourth and final purpose of the literature review was to investigate existing demand studies, not necessarily transfer-related, in order to help determine many demand-related impacts of alternative transfer policies. Reviewing the demand literature was an essential part of the study since operators may not be able to assess changes in consumer responses as well as they can estimate operational impacts. This part of the review, described in more detail in Section 4.5, focused on obtaining demand elasticities for wait, walk, and transfer times, and for fares for use in predicting the effects of transfer policy options.

Appropriate literature will be cited in the text wherever it relates to a given point. A bibliography of literature relevant to transfer-related issues is included at the end of this report as Appendix A.

Chapter 4
DESCRIPTION OF TRANSFERRING PASSENGERS

4.1 Introduction

The demand for transferring on a transit property clearly influences the type of transfer policy adopted. Relevant transfer demand characteristics include such elements as:

- The percentage of riders who transfer;
- Their socioeconomic and trip purpose characteristics;
- Transfer point locations; and
- Directional and temporal characteristics.

If a transit operator had all of this information for the existing system, transfer policy design would be made considerably easier. However, these data are usually difficult to obtain. For example, calculation of transfer rates from transfer slip counts is distorted by transit passes, through-riding, and free-fare zones. Surveys, which are the most reliable method for determining the characteristics of transferees, are difficult and expensive to administer.

Furthermore, information gathered on one property is usually not directly applicable to another, since transfer characteristics depend heavily on site-specific factors such as route structure and location of residential areas and major trip generators.

Notwithstanding these difficulties, it has been possible to construct a composite picture of transferring passengers. This picture outlines the ranges into which the above characteristics of demand can be expected to fall, and identifies the reasons why particular properties may be outside these ranges. This composite picture does not purport to describe the transfer characteristics on any particular property. However, by providing a guide to typical transfer characteristics, the composite picture should help the operator isolate the unique transfer-related features of his own property.

The results presented in this chapter are organized as follows. Section 4.2 focuses on the overall bus to bus transfer rate and how it is correlated with different transfer policies and site-specific factors, while Section 4.3 analyzes the transfer rate on properties with rail transit in a similar manner.

Section 4.4 examines the pattern of transferring at individual transfer points for bus/bus and bus/rail transferring. Since the amount of site-specific detail at this level relevant for describing cause and effect is greater than at the system level, the conclusions drawn will necessarily be more tentative. Transfer rates at a particular transfer point may differ enormously from the overall transfer rate, with further variation by time of day and day of week.

Section 4.5 reviews the demand-related literature as it applies to transfers. It identifies some useful sources for demand elasticities, particularly for wait, walk, and transfer

time. These elasticities are then related to the transfer rate, both on a system-wide basis, and at the level of individual transfer points.

Section 4.6 identifies typical characteristics of transferring passengers. It is based on market surveys and other information collected through the operator interviews. Section 4.7 then reviews the results of the previous sections in a broader context, and re-emphasizes the site-specific cause and effect nature of demand for transfers.

4.2 Overall Bus/Bus Transfer Rate

The <u>transfer rate</u> on a system is defined in several different ways in the literature and in practice. In this report the transfer rate will be the <u>percentage of transit person-trips which involve transfers between transit vehicles</u>. Persons who utilize a fare prepayment device will count as transfers, while persons who transfer more than once in the course of a trip are not double-counted. This definition of transfer rate is designed to measure the proportion of riders who would be affected by a change in transfer policy.

Calculation of the transfer rate (TR) is not necessarily a straightforward task. The following are examples of possible approaches, depending on the different data which are available locally:

1. The total number of person-trips (P) and the number of person-trips which involve transfers (PT); $TR = PT/P$.
2. Total boarding riders (R), and the total number of transfers (T), (under the assumption that no trips involve double transfers); $TR = T/(R - T)$.
3. Total boarding riders (R), number of person-trips involving a single transfer (T_1), and number of person-trips involving a double transfer (T_2); $TR = (T_1 + T_2)/(R - T_1 - 2T_2)$.

Other approaches could also be used to derive the transfer rate.

The transfer rate on a particular route must also be defined. The transfer rate from a route (or egress transfer rate) is defined as the percentage of passengers boarding that route who transfer to another transit vehicle. The transfer rate to a route (or access transfer rate) is the percentage of all passengers boarding that route who are transferring from another transit vehicle. Finally, the route transfer rate is the percentage of riders on that route whose trip has involved or will involve a transfer. This last number is similar to the transfer rate for the entire property in that it measures how wide an impact a change in transfer policy will have. Note that in all three cases the denominator is total rather than revenue passengers.

The accuracy of the calculated figure for the transfer rate is necessarily determined by the accuracy of the numbers which make it up. Counts of transfer slips can either yield total numbers of transfers or numbers of person-trips involving transfers, depending on whether a separate transfer slip is issued for each leg of a multiple-transfer journey. However, transfers by persons using transit passes would not be included in the transfer slip count, thus biasing the calculated transfer rate downward if pass users are included in the total ridership.

If pass users are not included in the total ridership figure, the relation between the actual transfer rate and calculated rate is uncertain. On one hand, if transfers are not free, leaving out pass users may bias the calculated transfer rate downward since pass holders do not pay for individual transfers and therefore may transfer more often than non-pass riders who pay for each transfer made. However, if most of the pass users are commuters who can get to their

work places (i.e., CBD) by transit without transferring, then leaving out pass users biases the calculated transfer rate upward.

On properties with no transfer slips or with a high pass-use rate, surveys or counts at major transfer points can supply transfer data. However, information obtained in this way may contain omissions and biases of its own. For example, a survey which asks users if they transfer on their usual transit trip will be giving disproportionate weight to the transfer patterns of infrequent users.

Wherever necessary, transfer rates cited in this report have been calculated using the available numbers for transfers and total ridership, with the assumption that transit pass users have the same approximate transfer rate as nonusers. This approach has been supplemented wherever possible by survey results. If no surveys had been taken, the transit operator was requested to give his best estimate of the volume of transferring passengers.

Given the uncertainty associated with any tabulation of transfer rates, it is still possible to construct a composite picture of transferring. The average bus/bus transfer rate on those properties where interviews were conducted is approximately 21 percent.[1] Several properties had a transfer rate on the order of 5 percent. On the other hand, transfer rates as high as 50 percent were observed, and rates on noninterviewed properties could even be higher. For the most part, however, the bus/bus transfer rate lies between 10 and 35 percent.

Transfer rates seem to be correlated with the transfer policy used. As shown below, properties which currently use timed transfers extensively have an average transfer rate of 28

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[1]All transfer rates in this section (4.2) refer to bus/bus transfers.

percent, while properties which did not use timed transfers extensively had an average transfer rate of approximately 18 percent.

	Average Transfer Rate (Percent)	Low (Percent)	High (Percent)
Properties which use timed transfers extensively	28	18	50
Properties which do not use timed transfers extensively	18	5	33

It should be noted, though, that the causal relationship here is not clear. Timed transfers may increase the transfer rate through a reduction in transfer time but conversely, the existence of travel patterns which result in a high transfer rate may make it more likely that a property will institute timed transfers. This is a good example of a problem encountered continually in this report -- indeed, in all cause and effect modeling -- of identifying which factors are causes and which are effects.

Another policy option which seems to be loosely correlated with bus/bus transfer rates is charging for transfers. Properties which do not charge for transfers have an average transfer rate of approximately 22 percent, while properties which do charge for transfers have an average transfer rate of approximately 18 percent.

	Average (Percent)	Low (Percent)	High (Percent)
Properties which do not charge for transfers	21.5	5	37
Properties which do charge for transfers	17.5	5	50

Once again, there is no obvious causal relationship. Having no transfer charge may attract new transfers, but a high bus/bus transfer rate may also lead to no transfer charge for political/equity reasons.

One transfer option which has an obvious direct effect on the transfer rate is through-routing. Individuals who ride through on the same bus traveling two bus routes are not counted as transfers. Therefore, it is not surprising that properties which have no through-routing have a higher average transfer rate (23 percent) than those properties which have some degree of through-routing (19 percent).

The size of the property also has a large influence on the overall transfer rate. The average bus/bus transfer rate in the large cities where interviews were conducted is somewhat higher than the average transfer rate in the small cities (20.3 percent versus 19.5 percent). However, when the properties which currently use timed transfers extensively (all of which are small) are separated from the remainder of the small properties, the relationship between size and transfer rate becomes clearer.

	Average Transfer Rate (Percent)	Low (Percent)	High (Percent)
Large properties	20.3	10	33
Small properties which do not use timed transfers	11.8	5	20
Small properties which do use timed transfers	30.5	18	50

It is reasonable to assume that this finding is a reflection of the increased dispersion of origins and destinations found on large properties. This leads to a higher volume of transfers than would be found in a smaller (geographical or population) city with employment and shopping concentrated in one central area. However, there is no reason why a particular small property cannot have a high transfer rate due to dispersed origins and destinations. Not surprisingly, several properties where interviews were conducted, both small and large, reported that increased employment and shopping outside of the CBD was followed by increased transferring.

A related factor is the size of the CBD. If the CBD is quite large, or not compact, individuals who are riding to downtown may find that their bus does not pass near their destination, necessitating a transfer to another bus. Even properties with relatively narrow CBDs can have significant amounts of transferring depending upon the coverage provided by individual routes.

There is no strong relationship between the presence of a grid bus system and the overall bus/bus transfer rate. A grid system cuts down on the need to transfer for cross-town trips. On the other hand, a grid system will usually have many more distinct transfer points, and people served by cross-town routes may have to transfer to go downtown. Several cities now are implementing plans to change from radial systems to a "bus transit center" concept,[1] which involves a grid route system connecting transit subcenters, plus neighborhood routes focused on these subcenters. This route restructuring is expected to increase the transfer rate significantly due to the "feeder" role of the neighborhood routes.

The emphasis in this section thus far has been on relating single characteristics of properties to their transfer rates. It is also quite informative to analyze how sets of characteristics affect the transfer rate. Figure 4-1 gives the average and range of the transfer rates for the properties in each of the original segmentation cells. All properties for which appropriate bus/bus transfer rate data are available (includes 28 of the 34 properties listed in Figure 1-1) are included in this figure.

Figure 4-1 implies that size of property and use of timed transfers are much more important in determining the bus/bus transfer rate than amount of transfer charge. Although, as noted before, the overall transfer rate of properties with zero transfer charge is higher than the transfer rate of those with nonzero transfer charge, this relationship appears to be due to the influence of the large properties and of the small properties with timed transfers. The use of timed transfers and size of property generally seem to be correlated with the transfer rate.

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[1]Among these cities are Portland, Oregon and Denver, Colorado. Both of these cities plan to have timed transfers between neighborhood routes at many of the transit subcenters.

Figure 4-1

AVERAGE AND RANGE OF BUS/BUS TRANSFER RATES
BY SEGMENTATION CELL[1]
(Percent)

Properties Which Do Not Use Timed Transfers Extensively

Transfer Charge	Small Size	Large Size
Full	Avg: 12.5 Range: (5-20)	
Reduced	Avg: 13 Range: (5-18)	Avg: 16.6 Range: (10-25)
Zero	Avg: 10.3 Range: (5-23)	Avg: 24.2 Range (11-23)

Properties Which Use Timed Transfers Extensively

Transfer Charge	Small Size	Large Size
Full		
Reduced	Range: 50 (only one property interviewed)	
Zero	Avg: 27.3 Range: (18-37)	

[1]Six properties not included because of lack of accurate transfer rate information.

SOURCE: Operator interviews.

4.3 Overall Bus/Rail Transfer Rate

The most useful information that can be conveyed by a transfer rate is a measure of how many riders would be affected by a change in transfer policy. With this in mind, the <u>intermodal rail transfer rate</u> is defined as the percentage of rail riders whose trip has involved or will involve a transfer to another transit mode (streetcars, buses, cable cars, trolley buses). If bus is the only other transit mode, then this number will be given in this report as the <u>bus/rail transfer rate</u>.

There are several ways to calculate the intermodal rail transfer rate (IRTR) based on various data and assumptions. The following provide some examples:

1. The total number of person trips on rail (RP) and the number of person trips on rail which involve transfers to or from other transit modes (RPT): IRTR = RPT/RP.
2. The total number of person trips on rail (RP), the number of person trips on rail whose access mode was other transit (AP), the number of person trips on rail whose egress mode was other transit (EP), and the number of person trips on rail for which both the access and egress mode was other transit (DP): IRTR = (AP + EP - DP)/RP.

The remaining calculation schemes given below all assume that for every access to rail by other transit there is a similar egress by other transit and vice versa (symmetry), and that there are no rail riders who use other transit for both access and egress on the same trip.

3. The total number of person trips on rail (RP) and the number of person trips on rail in which the access mode is other transit (AP): IRTR = 2AP/RP.

3A. The percentage of rail person trips in which the access mode is other transit (AR): IRTR = 2AR.

4. The total number of person trips on rail (RP), and the number of person trips on rail in which the egress mode is other transit (EP): IRTR = 2EP/RP.

4A. The percentage of rail person trips in which the egress mode is other transit (ER): IRTR = 2ER.

5. The number of person trips on rail whose originating mode is rail (OR) and the number of person trips on rail in which the egress mode is other transit (EP): IRTR = 2EP/(OR + EP).

It is necessary to present such a variety of alternative methods because data availability is often a constraint. Several properties have undertaken surveys which yield the intermodal rail transfer rate directly (e.g., Cleveland, Washington). Other properties know the percentage of rail person trips which access rail via other transit modes (e.g., Boston). Still others know how many transfers to other modes were given out on rail to originating passengers (e.g., Philadelphia). Figure 4-2 shows the intermodal rail transfer rate for each property interviewed, and whether or not this rate had to be calculated using the assumptions inherent in methods 3-5.

The average intermodal rail transfer rate on the properties in Figure 4-2 is approximately 47 percent, with a high of 70 percent and a low of 16 percent. Most rail transfer rates are in the range of 40-50 percent, except for New York City (16 percent), which can be explained by the very heavy rail coverage in Manhattan and parts of Brooklyn which allows passengers to walk to and from the subway.

The major determinant of the transfer rate seems to be the pattern of origins and destinations in the region in relation to the rail and other transit network. Specifically, consolidation of bus route termini at rail stations tends to, as might be expected, raise the intermodal rail transfer rate.

Figure 4-2

INTERMODAL RAIL TRANSFER RATES

Property	Year	Intermodal Rail Transfer Rate	Other Transit Modes Available	Comment
Atlanta	Projected	67	Bus	
Boston	1977	48[1]	Bus, Streetcar	
Chicago	1978	70	Bus	
Cleveland	1976	50	Bus, Light Rail	Transfer rate for heavy rail
New York City	1966	16[1]	Bus	
Philadelphia	1979	60[1]	Bus, light rail	Transfer rate for heavy rail
San Francisco	1974	27[1]	Bus	Transfer rate for passengers using stations served by AC Transit
Washington	1978	42	Bus	

[1]Calculated on basis of assumptions; see text.

SOURCE: Operator interviews.

It is important to note that the assumptions upon which some of the calculated transfer rates were based -- symmetry and lack of double transfers -- may not always hold. Properties with unbalanced bus/rail transfer charges have discovered that more rail riders take bus in the direction of free transfers (rail to bus) than in the other direction. For instance, in Washington, 17 percent more riders transfer from rail to bus than in the other direction. Even with no reduced fare transfers, there can be imbalanced transfer rates. A 1967 study in New York showed that 29 percent more riders transferred from bus to rail than in the other direction.[1]

It is also clear that some double transferring exists on all properties, but on some systems it can be quite extensive. A 1976 survey in Cleveland showed that 10 percent of heavy rail riders make two transfers in the course of a trip, while 3 percent of heavy rail riders make more than two transfers. Widespread multiple transferring on a property will cause the calculated (as opposed to surveyed) intermodal rail transfer rate to be higher than the actual rate.

4.4 Transfer Rates at Individual Transfer Points

The transfer rate, as measured over an entire transit system, is useful for determining the overall magnitude of the transfer problem, and for indicating some cause and effect relationships in highly aggregated form. However, most transfer policy options, such as schedule coordination,

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[1] EBS Management Consultants, Interim Report: Transfer System and Fare Structure, prepared for Office of Transportation Administration, New York City and NYC Transit Authority, New York, 1967.

through-routing and dynamic control, must be evaluated for application at particular transfer points. The operator thus needs to examine transfer flows in more detail in order to design an appropriate transfer policy.

Clearly, much of the transferring that goes on in many systems is concentrated at particular points. The transfer rates at these points can vary greatly from the average overall transfer rate for the system. In Memphis, for example, the overall bus/bus transfer rate was estimated to be approximately 16 percent. At the major transfer point, though, a survey showed that over the entire day, more than 60 percent of the people waiting there were in the process of transferring between buses. Furthermore, an on-board survey revealed that on one segment of a route between downtown and a major trip generator (the Mid-South Medical Center), over 85 percent of riders transferred to reach their destination.

Similar results are obtained when the bus access transfer rates at different rail stations on the same property are compared. In Chicago, the proportion of rail passengers using particular stations who arrive by bus varies from 12 percent up to 75 percent. In San Francisco in 1974, the proportion of passengers arriving at rail stations serviced by AC Transit who transferred to buses ranged from 6 percent to 60 percent. As a final example, at a selection of major rail stations in Boston, the proportion of rail riders accessing the station by bus or streetcar ranged from 13 percent up to 65 percent.

Bus/bus transfers can usefully be discussed and classified by location. Probably the most prevalent type of transfer is the cross-town transfer made by a rider traveling from one point outside of the CBD to another point outside the CBD. On a radial system, most transfers of this type occur in the CBD. On larger grid systems, though, the transfer point does not have to be downtown.

A second type of bus/bus transfer is the trunk line transfer. This involves a transfer from a cross-town route to a trunk line or vice versa to get to or from downtown. This is commonly found in larger cities which have a grid system of routes. Because there may be multiple cross-towns intersecting multiple trunk lines, the volume of transfers are often spread among many transfer points, with the individual choosing the most advantageous transfer point for himself.

Distributor/feeder transfers form the third major type of bus/bus transfer. They are characterized by one leg of the trip being much shorter than the other leg. An example would be a rider who takes a bus into the CBD, and transfers to another bus which he rides for a short distance within the CBD to his destination. Often this type of transfer will involve a shuttle or loop bus downtown. Downtown distributor transfers are particularly interesting because they represent a group of riders who are likely to have the option of walking instead of transferring. Hence, these people may be highly sensitive to changes in transfer level of service.

For bus/rail transfers, another set of categories can be established. There are "forced" bus/rail transfers, which occur when bus route consolidation (see Chapter 6) has taken place, and most buses turn back at the rail station. There are also local/express transfers, in which a rider will transfer from a bus to a parallel rail line. Finally, there are "continuation" transfers, where bus routes extend radially into lower density areas than rail lines. These categories are not meant to exhaust the different forms of bus/rail transfers and may not be mutually exclusive. However, they do indicate some general groupings.

Transfer flow at a transfer point is not only a function of location, but also of time of day and day of week. This fact has a profound influence on the types of transfer policy

components which may be applicable. For instance, on several properties, the bus/bus transfer rate (as well as volume) is much higher during peak hours than off-peak. Since the direction of transfers may be more pronounced during peak hours (especially for bus/rail transfers), and frequency of service is higher, the consequences of different transfer policies may be affected. For example, transfer policy options such as schedule coordination involve vehicles on two routes arriving in a set order, and hence favor one direction of transferring over another.

The overall transfer rate also tends to vary somewhat by day of week (weekday, Saturday, Sunday). However, available route-by-route transfer data indicate that even when the overall rate of transfers does not change from weekday to weekend, the transfer flows on individual routes do change. Pairs of routes which have a high transfer rate during weekdays may have a low rate on weekends, or vice versa. The exact pattern depends on the location of major shopping and employment centers which attract trips in relatively different proportions by time of day and day of week.

4.5 Demand Literature Review

An important part of the description of transferring passengers is their sensitivity to alterations in various attributes of the transfer (i.e., transfer wait time, transfer walk time). Later chapters of this report examine the ridership consequences of each transfer policy component on the basis of operator interviews and reasonable ranges of demand elasticities. This section focuses on the evidence presented in the available demand literature concerning the demand for transferring among transit passengers.

There is a limited amount of demand literature which treats transferring explicitly as a separate component of level of service. One empirical study in Stockholm, Sweden, estimated a model using separate equations for trips which included a transfer and those which did not.[1] According to the estimated model (which may not apply to U.S. properties), one bus/bus transfer has a burden equivalent to between 49 and 54 minutes of additional line-haul time, or between 14 and 16 minutes of additional (nontransfer) waiting time, or approximately 33 minutes in additional excess time (walk time plus some wait time, but not transfer time). The average walk and wait times for transfers are not presented.

A more relevant San Francisco study used transfer wait time as a separate independent variable.[2] The aggregate bus demand elasticity with respect to bus transfer time was -0.26, where aggregate demand is calculated from a weighted sample reflecting the distribution of bus transfer time over the population. This compares to an aggregate bus demand elasticity with respect to first wait time of -0.17.

Many other demand studies have included transfer wait time and transfer charge as part of other variables, such as out-of-vehicle time and total transit cost. According to one survey of demand elasticities, elasticities of bus demand with respect to bus cost have ranged from -0.1 to -0.58.[3] In the

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[1] S. Algers _et al._, "Role of Waiting Time, Comfort, and Convenience in Modal Choice for Work Trip," _Transportation Research Record_ 534 (Washington, D.C., 1975).

[2] D. McFadden, "The Measurement of Urban Travel Demand," _Journal of Public Economics_ 3 (1974).

[3] Y. Chan and F. L. Ou, "A Tabulation of Demand Elasticities for Urban Travel Forecasting," Pennsylvania Transportation Institute, August 1977.

examples and analyses presented in this study, fare elasticities will be assumed to fall in this range with transit patronage being most sensitive to price changes at off-peak times, for short journeys, and in low traffic congestion areas.[1]

Elasticities for wait, walk, and transfer time (combined) will be assumed to range from -0.7 as a low[2] up to -1.02 as a high.[3] The prevailing finding reported in the literature is that passenger sensitivity to excess time is greatest for infrequent service and for shopping trips.

It should be emphasized that while these elasticities will play a role in the analysis of the ridership effects of different transfer policy options, they will be modified where necessary using site-specific data collected in the interviews. Additional elasticities will also be cited from the literature and used when appropriate.

4.6 Transfer Characteristics

This section focuses on the differences between transferring and nontransferring passengers. Because of data availability, this section is concerned primarily with bus/bus transfers. Figure 4-3 shows typical ranges of bus/bus transfer

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[1] Michael Kemp, "Policies to Increase Transit Ridership," Urban Institute, Washington, D.C., September 1977.

[2] T. A. Domencich, G. Kraft, and J. P. Valette, "Estimation of Urban Passenger Travel Behavior: An Economic Demand Model," Highway Research Record 238 (Washington, D.C.: HRB, 1968), pp. 64-78.

[3] A. Talvitie, "An Econometric Model for Downtown Work Trips," Chicago Area Transportation Study, December 1971.

Figure 4-3

TYPICAL BUS/BUS TRANSFER RATES BY MARKET SEGMENT[1]

Market Segment	Typical Range of Transfer Rate Low	High
Income:		
(>$15,000)	12	25
(<$15,000)	18	36
Elderly		
(>60 yrs)	19	30
Young		
(<16 yrs)	30	37
Male	16	29
Female	18	33
Frequent riders	18	27
Infrequent riders	30	34

[1]Transfer rates for these market segments on some particular property may fall outside of the ranges listed here.

SOURCE: Based on operator interviews and market surveys.

rates for some market segments derived from both market surveys and qualitative data collected from operators.

The first pattern which emerges is that low-income riders are more likely to transfer between buses than higher income riders. A reasonable rule of thumb seems to be that riders with household incomes below $15,000 are about one and one-half times as likely to transfer as part of a transit trip as riders with household incomes above that figure.

Several explanations can be advanced for this relationship. Patterns of employment may lead to white-collar jobs being in the CBD, so that transferring is not necessary to reach them. Along similar lines, suburbs and outlying areas may have express routes directly into the CBD. The third and most likely explanation is that higher income individuals are more likely to have a car available to them, and are thus less likely to accept the burden of a transit trip which requires transferring.

A second group with above average rates of transferring is youth. This can be attributed to their lack of available automobiles, the relatively low value that they may place on time, and the low deterrent effect of the walking that may be associated with transferring. It should also be noted that on some properties, students attend schools which are not in their neighborhoods, and must use more than one bus to get there.

Elderly people, on the other hand, tend to have a lower transfer rate than riders overall. The change of vehicles associated with transfers appears to discourage the elderly from taking transit trips which involve transfers. This relationship between age and transferring is substantiated by a bus user survey in Memphis, which showed that having to transfer was more likely to cause the elderly to rate bus service poorly than other groups. In addition, several

operators of rail properties have suggested that elderly are less likely to transfer between bus and rail than other groups.

The data collected also suggest that users who ride infrequently are more likely to transfer between buses than those who ride frequently. The increased need for infrequent riders to make bus/bus transfers implies either that low frequency trips, such as shopping and social-recreational, are more likely to involve transfers, or that the onerous nature of transfers discourages riding for nonwork trip purposes. To the degree that the second hypothesis holds, easing transferring will tend to increase ridership.

4.7 Discussion

In the words of one experienced transit professional: "The worse the transfer system, the more people <u>have</u> to transfer; the better the transfer policy, the more people <u>want</u> to transfer." This dichotomy illustrates the simultaneity of the supply- and demand-side behavior so common but so unrecognized in transit and transportation planning. On one hand, the relationship between the patterns of origins and destinations and the route structure determines who will have to transfer when transit is used. On the other hand, the operator has options available which can influence the attractiveness of transferring, which in turn affects the amount of transferring which actually occurs.

The aggregate system-wide picture presented in this chapter serves to illustrate the above dichotomy. The size of a property, measured in population of service area, can serve as a proxy for much more complex relationships between route structure and origin-destination flows in determining bus/bus transfer rates. This surrogate relationship says that the

number of people who have to transfer because of a more dispersed set of origins and destinations and a route structure which has more transfer points tends to increase with the size of the property. On the other hand, the attractiveness of transfers may be increased by increasing schedule coordination or implementing extensive timed transfers, reducing transfer charges, and, in the extreme, eliminating transfers altogether by through-routing vehicles.

The same dichotomy exists on a more detailed level. For example, low-income riders transfer more often than high-income riders because they have to, not because low-income riders find transfers more attractive. Elderly riders, though, transfer less than other riders because they find transfers less attractive.

Clearly it is easier to generalize about demand-side behavior, the subject of this chapter, than about the multidimensional effects of different transfer policies when used on different properties, and in different settings. This chapter has provided a composite picture of transferring which suggests transfer patterns to look for on a property. However, There is no substitute for a detailed analysis of how many people are transferring, who they are, and where and why they are traveling.

Each of the next eleven chapters each describe the current practices and consequences associated with the individual transfer policy options outlined in Chapter 2. Each chapter contains five sections. The first section is a summary description of the transfer policy component and its application. The second section is an in-depth review of current practices connected with that component as applied to bus/bus transfer policies. The third section is a similar review of current practices connected with that component as applied to bus/rail and rail/rail transfer policies. The

fourth section analyzes the cost, user satisfaction, ridership, and revenue consequences which follow from the use of that policy option. Differences between the consequences of using the option for bus versus rail transfer policies are detailed as appropriate. Finally, the fifth section provides a synthesis of findings, highlighting relationships between consequences of the option and various site-specific characteristics of the property on which it is implemented.

Chapter 5
DISTANCE BETWEEN ROUTES AT TRANSFER POINTS

5.1 Introduction

The first transfer policy component to be considered is the routing option affecting the distance between routes at transfer points. One of the basic considerations of transferring is the walk required between vehicles. At a minimum, there may be only a few feet between connecting buses. At the other end of the spectrum, passengers may have to walk many blocks horizontally and some distance vertically in order to transfer. Walking distance is an important element in the determination of user satisfaction.

The first transfer policy component therefore involves the physical placement of route termination points or other stops at which transfers are possible. It should be noted, however, that the operator's ability to make changes in the spatial separation of routes may be constrained by physical and regulatory options beyond his control. Also, placement of rail routes tends to be difficult and expensive to alter in the short or medium run, and rerouting buses to change the spatial separation of routes at a transfer point will often affect the level of service provided to nontransferring riders as well.

Section 5.2 explores current practice on U.S. transit properties concerning the separation of bus routes at transfer points. This section considers in detail the major strategies available for properties in dealing with bus/bus transfer distance. These include the passive "do-nothing" approach, on-street terminal areas, off-street terminal areas, bus transit malls or streets, grouping of routes into subfoci, and grid route structures. The reasons why operators may choose to reduce or not reduce transfer distance are outlined. Section 5.3 covers the same topics as 5.2 for bus/rail and rail/rail transfer distance.

Section 5.4 describes the consequences of reducing spatial separation for bus/bus transfers, with a separate subsection on how the consequences differ for bus/rail and rail/rail transfers. Evidence is presented comparing the magnitude of the effects of spatial separation and transfer wait time. A sample analysis of the costs and revenue benefits of reducing spatial separation is presented.

Section 5.5 synthesizes the results of the previous sections to suggest where different strategies for reducing spatial separation are applicable, and outline the tradeoffs among their consequences. In addition, the interaction between spatial separation and other transfer components is discussed.

5.2 Current Practice -- Bus

Amount of Separation

Approximately one third of the properties where interviews were conducted use separations of 500 feet or more between routes where direct transfers were expected to occur. This distance is measured at the closest approach of the two routes. Several properties were found to have a spatial separation of about 1,000 feet. Assuming an average city walking speed of three miles per hour, this means just under a four-minute walk.

On at least one property (Providence), there were a sizable number of riders who had to walk 1,500 feet to transfer, which would equivalently take about six minutes.[1] Given that certain user groups, such as the elderly, walk slower than average, and many factors, such as traffic signals, may cause additional delays, potential transfer walk times of ten minutes or more can be expected.

Lengthy transfer distances are found primarily on larger properties. This is reasonable since the properties have more routes between which riders can transfer and more problems finding an appropriate spot for routes to meet. Small properties with extensive timed transfers, where buses on all routes arrive simultaneously, encounter similar space problems.

Reasons for Spatial Separation

Transit operators have several reasons for requiring long transfer distances. Foremost among these is the difficulty of finding a place where all or most routes can meet. Large numbers of buses, even if they do not all arrive at once, need a considerable amount of space to stop and lay over. Ten 40-foot buses, all stopped at the same time, require over 400 linear feet of curb space. The property cited above as having a 1,500 feet transfer distance (Providence) regularly has about 23 buses stopped at or near terminal locations during the evening peak hour. Clearly, there are constraints on how these parked buses may be arranged within the CBD.

An additional problem in route clustering is the possible traffic congestion produced if many bus routes go to the same terminus. If the transfer point is at a major activity center,

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[1]Alan M. Voorhees and Associates, Providence Auto Restricted Zone Technical Appendices, UMTA, June 1977.

the existing congestion may produce schedule adherence problems for buses, and lead operators to turn back routes away from the center. Conversely, the buses themselves may contribute further to existing traffic congestion problems if they travel into the CBD.

The layout of both routes and streets in the area surrounding the transfer point may also contribute to transfer distance. For example, if routes are arranged in a radial pattern, then all bus routes naturally proceed to the same point. However, if routes and streets are in a grid, parallel routes will usually not meet without circuitous detours.

The grid example is a special case of a large class of properties where the street layout makes some lengthy transfer distances difficult to avoid. In cities with irregular street patterns, buses may have "natural" routes which do not lend themselves easily to meeting all other routes. The need to serve the usually more numerous nontransferring ridership may constrain attempts to reduce transfer distance. Available space, congestion, and street layout, therefore, are the principal determinants of transfer distance for many properties.

A fourth reason for not minimizing transfer distance, which may be less prevalent than the others, is having too many riders (rather than buses) at any one place. At a major bus stop/transfer point, riders waiting for buses may hinder pedestrian movements, and have detrimental effects on particular retail establishments. If bus stops are moved in such a way as to alleviate this problem, the spatial separation of some routes may be increased.

Alternatives for Reducing Spatial Separation

Given the factors listed above, several different strategies are available to deal wth the problem of spatial

separation. These are listed in Figure 5-1, together with a sample of cities which employ each strategy. Of course, there is always the "do-nothing" alternative, which consists of letting bus routes be determined by operational and nontransferring demand considerations. This may or may not lead to long transfer distances.

The first "active" strategy in Figure 5-1 is to try to place the termination points of all routes in a one- or two-block area. For a small property, with only a few radial routes, this is usually easy to accomplish. Even on a large property, it may be possible to implement this strategy. Cleveland, for example, is a large city where the great majority of routes coming into the CBD terminate in a two-block area.

Another possibility open to operators is an off-street terminal facility. This avoids several of the difficulties associated with having a large number of buses on the street in the same area. However, an off-street facility does not solve the problem of a route structure which does not allow for bringing routes together. It also can entail a major capital expenditure. The off-street facility can have both buses and people completely inside a building, have the buses outside and people inside, or be completely outside. Brockton, Massachusetts recently built an outdoor facility with berths for over 15 buses.

In cases where a separate off-street facility is not feasible or cost-effective, and the number of buses is too large to bring them all together at the same place, a bus transit mall may be appropriate. A bus transit mall is a street designated for buses, which all or most routes coming into the CBD utilize. For the purpose of this study, the important feature of a bus transit mall is that transfer distance is near zero, since most routes move past the same

Figure 5-1

SPATIAL SEPARATION STRATEGIES AND SAMPLE CITIES FOR BUS/BUS TRANSFERS

Strategy	Cities
Central On-Street Transfer Point or Area	Cleveland Lafayette Westport Albany
Off-Street Transfer Facility	Brockton
Transit Mall	Portland, OR Denver (planned) Memphis
Sub-foci	Buffalo Fresno
Grid	Indianapolis Baltimore

Source: Operator interviews.

points. Portland, Oregon has such a bus transit mall.[1] It is also possible to obtain the same effect by routing all buses down the same street without formally setting up a transit mall. Columbus, Ohio is a large city where almost all buses coming into the CBD travel for some distance on a single main street.

The alternatives presented above collect all routes into a single area to minimize transfer distance. However, it is clearly possible to set up a network of routes where buses terminate at different points, yet each route crosses most or all of the others at some point, thereby facilitating transfers. One way of doing this is to establish several subfoci, such that each route in the CBD terminates at some subfocus, and each subfocus has only a few terminating routes. One relatively common way of accomplishing this is to collect into each subfocus routes which service the same geographical region --e.g., west side routes with west side routes, etc. By placing each subfocus on the side of the CBD opposite the point where its routes enter, the intersection or parallel operation of most or all routes can be ensured.

The extreme case of spreading transfer points over a wide area is a grid network. As explained before, a grid network of routes guarantees that routes which are perpendicular to each other will cross and meet, with a very short transfer distance. Routes which are parallel do not necessarily cross, which may tend to increase potential transfer distance. It should be noted that the actual transferring which occurs between parallel routes depends heavily on their eventual divergence, since, all things being equal, nothing is gained by transferring between perfectly parallel routes.

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[1]Crain and Associates, Streets for Pedestrians and Transit: A Site Report on Transit Malls in the United States, prepared for DOT/Transportation Systems Center, Cambridge, Mass., August 1977.

A factor which is present with any degree of spatial separation are the "pedestrian obstacles" encountered between vehicles. Pedestrian obstacles include such experiences as crossing busy streets, negotiating parking lots, encountering "riff-raff," etc. Any of these can increase the psychological distance of a given transfer, as well as actual transfer time. Indeed, pedestrian obstacles may be the most onerous feature of long transfer distances. These obstacles must be taken into account whenever the merits of alternative strategies for dealing with spatial separation are assessed.

5.3 Current Practice -- Rail

Amount of Separation

In contrast to bus/bus transfers, bus/rail and rail/rail transfers often involve vertical as well as horizontal separation between routes. Furthermore, the path between vehicles is not necessarily direct, as it usually is for bus/bus transfers. Buses may line up in a long row to discharge their passengers at substantially varying distances from the rail entrances, turnstiles or rail platforms. Rail train lengths can be quite long (e.g., up to 600 feet in New York City), affecting the distance that alighting passengers must walk to stairs, escalators, station exits and bus loading bays. Hence bus/rail and rail/rail transfer distances are typically lengthier than the distances for bus/bus transfers.

Although there is no straightforward method of converting spatial separation to time spent walking (given the mix of horizontal and vertical distance, availability of elevators and escalators, and differences in walking speed), it is possible to cite examples of the ranges of walking times which can be expected. Across-the-platform transfers between trains (found on several rapid rail systems) typically involve a very short walking time. Across-the-platform transfers between commuter

trains and buses (as found in Detroit and Westport) can take up to five minutes for some passengers, due to the length of the commuter train. In Cleveland, subway riders alighting at Public Square are given approximately four minutes to reach the surface and board waiting buses.

In cases where passengers must walk from one end of a lengthy station to the other, climb several flights of steps, and then walk another lengthy distance to a bus, transfer times of 10 minutes or more for elderly passengers are not unreasonable to expect.

Reasons for Spatial Separation

There are several important reasons why, in the absence of mitigating strategies, the distance associated with rail/rail and bus/rail transfers typically exceeds that associated with bus/bus transfers. The first of these is the presence of grade separations between rail platforms and surface streets or other rail platforms. Many rapid rail systems have across-platform transfers between rail vehicles at some transfer points. However, vertical distance between connecting vehicles at bus/rail or rail/rail transfer points is the norm.

The second major reason for long rail transfer distances are construction constraints imposed by station structures. These increase the horizontal distance between connecting vehicles, since buses are typically outside of the station structure. Moreover, in underground and elevated stations, riders may have only a few points from which to exit the rail platform, increasing the horizontal distance.

The third important reason for long rail transfer distances is the low priority assigned to bringing buses closer or into the station. Rail stations are often located in areas of maximum activity density, and may contribute to relatively intensive adjacent land use, making it even more difficult to accommodate buses nearby. One example of this is at the

Flushing train station in New York City, which is one of the busiest bus route termini in the city. The opportunity existed there to create an off-street bus facility which would have lessened the horizontal separation for many bus/rail transferees. However, there were higher priority uses for that land, and the terminal area was not built. In general, it may be very expensive to acquire off-street land, or the land may simply not be available for the purpose of reducing rail transfer distances.

A fourth reason for spatial separation of routes is, interestingly enough, to encourage shopping. When the 69th Street terminal was built in Philadelphia, it was shared by two separate transit companies. In order to help pay for the terminal, shops were built and rented inside the terminal building where passengers transferring between the two companies would have to walk past them. The same reasoning can be found at other transfer locations.

Finally, a key reason for the lack of provisions taken to facilitate bus/rail and rail/rail transfers is purely historical. Rail facilities are relatively fixed in space compared to bus routes. Therefore, if facilities to reduce spatial separation of routes are not included in the original construction of the station, they may be totally impractical to add afterwards.

Alternatives for Reducing Spatial Separation

As in the case of bus/bus transfers, there are several different strategies available to the operator for dealing with the spatial separation associated with bus/rail or rail/rail transfers. These are listed in Figure 5-2, together with a sample of cities which employ them. This list does not include those strategies which would involve changes in the rail right-of-way itself. That is, both the vertical grade separation and the horizontal alignment of the rail line(s) are taken as given.

Figure 5-2

SPATIAL SEPARATION STRATEGIES AND SAMPLE CITIES
FOR BUS/RAIL AND RAIL/RAIL TRANSFERS

Vertical Separation

Reduction of Perceived Vertical Distance
(e.g., Elevators and Escalators)

Washington, D.C.
Atlanta
San Francisco (BART)

Reduction of Actual Vertical Distance
(e.g., Bus Tunnels)

Boston (Harvard Square)

Horizontal Separation

Off-Street or On-Street Bus Terminal Facilities

Cleveland (Public Square)

Vertical (over/under) Alignment of Bus and Rail Routes

New York City (Stillwell Avenue)
Toronto
Washington, D.C.

Bus Ramps into Station

Boston (Ashmont)

Once again, of course, the do-nothing alternative of building the rail facilities and then letting the buses stop at the nearest convenient location has always been available. This occurs at the great majority of existing rail stations. With certain exceptions (e.g., commuter rail in low-density areas), this typically leads to significant transfer distances.

However, depending upon the interpretation of Section 504 of the Rehabilitation Act of 1973, the do-nothing strategy may no longer be possible. It may become necessary to provide convenient access (via elevator, etc.) to existing grade-separated structures, as well as to new ones. This is an example of the first active strategy presented in Figure 5-2, namely reducing the perceived vertical separation between routes. This strategy is obviously easier to implement in the building of new stations than in the reconstruction of old ones.

The second active strategy is to actually reduce vertical distance by bringing the buses up or down to the level of the rail platform. This involves building bus access into the station itself. Harvard Square in Boston is one example where a bus tunnel takes most of the buses terminating at the station down to the approximate level of the underground rail platform.

Both strategies described above attempt to reduce vertical transfer distance. Strategies for reducing horizontal transfer distance are also available. These include the strategies described in Section 5.2 for bringing buses closer together (e.g., off-street terminal facilities, central on-street transfer point). Other possible strategies include bringing buses directly over or under the rail platform through use of a separate off-street area (as is done in Toronto and at the Stillwell Avenue Station in New York City, among others), and having bus ramps go into the station itself.

5.4 Consequences

This section outlines the consequences of operator actions taken to reduce the distance between routes at transfer points. This analysis focuses primarily on the consequences (operator cost, user satisfaction, ridership and revenue) of reducing route separation for bus/bus transfers. It will be assumed for this analysis that it is physically possible to decrease the transfer distance, and that buses can in fact be brought closer together. A separate subsection outlines how consequences of this transfer component vary when applied to bus/rail and rail/rail transfers.

Bus Transfers

Operator Costs

The first type of consequence involves operator costs. If two bus routes are initially some distance apart, and then are moved closer together, the most obvious cost effect occurs through changes in vehicle miles traveled (VMT) and bus hours. The change in VMT is not necessarily commensurate with the change in transfer distance. It is possible that alterations in routing (e.g., different turn-around procedures) can make the change in VMT very low for a given change in transfer distance. Alternatively, one-way streets and other obstacles may cause VMT to increase much more than would be expected from the transfer distance decrease.

Given these variations which occur in practice, it is still useful to examine the cost consequences of a hypothetical situation where the change in VMT is only influenced by the change in transfer distance itself. Consider two bus routes, with termination points 1,000 feet apart. If the routes are changed so that they coterminate, without altering turn-around

mileage, layover time, or the existing route length, then the added VMT amounts to 2,000 feet per trip. If it is assumed that buses travel in the CBD at 10 m.p.h. (exclusive of layovers), then each round trip adds just over two minutes of bus run time. If there are 30 trips per day on a route (equivalent to half-hour headways from 6 a.m. to 9 p.m.), then 1.2 additional bus-hours per day are required, or approximately 360 bus-hours per year. At an approximate cost of $20 per bus-hour, the annual operating cost of reducing the separation of two routes in this situation is approximately $7,200.

It should be stressed that this $7,200 figure may be strongly influenced by site-specific factors on any particular property. First, as mentioned above, routing alterations may lead to VMT changes which are greater or less than calculated. Second, different numbers of trips, running speeds, and costs may be appropriate. Third, the calculation assumed that all other factors remained equal. If the operator allows headways to increase by somewhat over two minutes, his only increase in cost is in purely mileage-related costs (no increase in bus-hours). If these are estimated at $.50 per bus-mile (a high figure), then the additional cost in the hypothetical example above would be reduced to approximately $1,800 per year.

In terms of how operating costs vary over the different strategies outlined in Section 5.2, the subfocus approach is probably the most expensive if transfer distance is to be minimized. If routes terminate on the opposite side of the CBD from which they come in, there is an overlap in the center where all buses go. This overlap is more expensive than having all buses terminate in the center, but it may also have significant nontransfer effects associated with the increase in service frequency downtown (see Chapter 6).

Capital costs may also be involved if the different strategies affect bus fleet size or equipment needed for dispatching. Capital costs are, of course, a direct consequence of those strategies which involve construction of an off-street facility or a transit mall. As outlined earlier, facilities for bus/bus transfers and related capital costs are not within the scope of this study. However, for illustration purposes, the off-street outdoor transfer facility in Brockton, Massachusetts, for 15-20 buses, cost approximately $600,000 dollars (1978).

User Satisfaction

User satisfaction is the second major consequence to be considered. It is clear that transfer walk distance, if for no other reason than increased out-of-vehicle-travel-time (OVTT), has a negative effect on user satisfaction. However, there are factors which make transfer distance more onerous than pure OVTT. First, of course, is the physical effort required to walk some distance. This affects some groups, such as the elderly or shoppers with packages, more than others. Pedestrian obstacles encountered on the walk also have a negative effect on user satisfaction.

The higher burden of walk time relative to wait time is documented in a logit work modal choice model estimated by Domencich and McFadden.[1] In that model, the estimated coefficient for transit walk time is three to four times that of transit wait time or in-vehicle time. For shopping trips the corresponding ratio was six to one. This lends support to the notion that spatial separation of routes at a transfer point may have a greater effect on user satisfaction than the transfer wait alone.

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[1] T. Domencich and D. McFadden, Urban Travel Behavior (Amsterdam: North-Holland Publishing Company, 1973).

Another factor in user satisfaction is comprehensibility of the transfer system. Transfers between two buses which stop adjacent to each other are easier to understand than transfers which involve a walk of several blocks. This applies particularly to the infrequent user, who may either not know of the transfer possibility, or have to walk through unfamiliar streets to make a transfer.

A lengthy transfer distance may also decrease user satisfaction by not allowing people to see when their connecting bus has arrived, thus contributing to missing it. Riders may feel better if they can see their connecting bus when they get off their first bus. On the other hand, if a rider can see his or her connecting bus, but cannot make it because of the distance, this may lead to excessive frustration, and decreased user satisfaction. Presumably, this would be minimized if connecting buses were held in such instances (see Chapter 8).

It is certainly difficult to measure precisely the degree of change in user satisfaction attributable to changes in spatial separation. However, users do reveal preferences in their behavior which provide some means to compare changes in user satisfaction caused by this and other factors. The first of these is found on those properties where some routes run parallel, one or two blocks apart, for some distance before actually coming together. Passengers transferring between the two routes can save in-vehicle time and keep their average transfer wait time approximately the same by getting off before the buses come together and walking the intervening blocks. Depending on the respective schedules and service reliability of the two routes, the transferring passengers may also be able to increase their chances of connecting with the other bus in this way.

In practice relatively few people take advantage of these "walking" transfers. For the most part, transferring passengers do ride all the way to the intersection point. Two reasons may contribute to this behavior. First, walking itself may be quite onerous. Second, and perhaps very important, transferring between adjacent routes is less uncertain than walking the one or two blocks between separated routes.

Another indication of the decrease in user satisfaction associated with transfer distance is the use of intermediate buses. Taking an intermediate bus has several disadvantages. It leads to a trip which has two transfers instead of one, inherently higher total average transfer wait time and total variance of transfer time, and possibly higher cost (depending on fare structure). Its principal advantage is that an intermediate bus cuts down on total transfer walk distance. Available information indicates that a spatial separation of three or four blocks is sufficient to induce many people to take an intermediate bus, even in the face of the above disadvantages. This indicates, as suggested before, that walk distance is perceived to be relatively onerous in comparison with other aspects of level-of-service. The physical effort involved and the decreased comprehensibility of the transfer system appear to be the principal reasons for the user dissatisfaction associated with a significant transfer distance. The most affected groups seem to be the elderly, shoppers, and infrequent riders.

Ridership

These effects on user satisfaction have direct consequences for ridership. It is not known exactly how much a lengthy transfer distance tends to discourage ridership. Certainly there are a sizable number of people who currently walk four or more blocks to transfer without great complaint. However, it is reasonable to infer from the user

dissatisfaction associated with spatial separation that reducing the transfer distance will increase ridership and transferring, with the largest increase coming among the elderly, shoppers, and infrequent riders. Any accurate estimation of these increases would require an origin-destination survey, or some other site-specific indication of desired travel patterns.

However, for the change in route separation for which cost consequences were estimated above, it is possible to make order-of-magnitude estimates of ridership changes based on elasticities. Under several reasonable assumptions, the demand elasticity for work trips with respect to total transit walk time for people who have to walk 1,000 feet to transfer at a particular transfer point can be estimated to be approximately one (actually 1.06).[1]

If the transfer walk amounted to four minutes, and total transit walk time amounted to nine minutes, eliminating the transfer walk would represent a 45 percent decrease in total walk time, and therefore produce about a 50 percent increase in the number of transferring work-trip passengers at that transfer point. For shopping trips the percentage increase would be even greater, since the coefficient on walk time is twice as large. These would all be additional transit passengers who previously used auto. There may also be people who used one bus and then walked to their destination prior to

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[1]The coefficient on transit walk for work trips (in Domencich and McFadden, op. cit.) is -0.147. Assuming five minutes initial and final walk time and 20 percent modal split for people who would have to walk 1,000 feet (four minutes) to transfer if they rode transit,

$$\eta \text{ walk} = (1 - 0.2)(-0.1472)(9) = 1.06$$

the reduction in spatial separation, but who may now transfer (i.e., a distributor/feeder transfer) to a convenient second bus. Depending on how far they walked previously, the transfer demand elasticity with respect to walk for these people may also be greater than one.

It should be emphasized that this ridership example is purely hypothetical and is not intended to be applied directly to any particular property. However, an elasticity of demand with respect to transit walk time of unity is quite consistent with operator impressions and opinions.

Revenue

The change in revenue which can be attributed to reduction in spatial separation is proportional to the change in ridership, though special fares which apply to the elderly, etc., must be accounted for. Since the exact change in ridership is impossible to estimate, so is the change in revenue. However, it is possible, using the example of cost consequences presented at the beginning of this section, to show that it is not unreasonable to expect that the additional revenue generated by the improved quality of service could exceed the extra $7,200 operating cost.

The number of transferring passengers, by the previous example, may possibly increase by 50 percent with the elimination of transfer walk distance. Thus, the revenue collected from passengers who transfer (including their base fare) will increase by 50 percent as well. In order for the additional revenue induced by the reduction in transfer distance to exceed $7,200 (the cost of the reduction), the initial total revenue collected from passengers who transfer must exceed $14,400 yearly, or $48 daily. Assuming a $.50 base fare and no transfer charge, this means there must be at least 48 passengers who transfer per day prior to the change in

transfer walk distance, or less than two passengers transferring per trip. It appears, then, that there are many situations where reducing spatial separation can result in a revenue increase greater than the cost increase.

Rail Transfers

The running cost consequences (bus VMT and VHT) of reducing the spatial separation between buses and rail do not differ substantially from the running cost consequences associated with bus/bus transfers. However, the capital cost consequences associated with reducing bus/rail and rail/rail transfer distances are much greater. Almost all of the rail transfer strategies described in Section 5.3 require some capital investment because changes in facilities are involved. It is not within the scope of this study to estimate capital costs (for example, for rail stations with and without bus tunnels). Site-specific considerations preclude such estimates. However, it is easy to make two readily apparent observations concerning the capital costs of different strategies.

The first observation is that it costs much more to implement a strategy after a station is built than while it is being built. This holds for all strategies previously described -- elevators, escalators, bus bays, bus tunnels, etc. Even a system such as BART, which is relatively new, finds it prohibitively expensive to add bus bays now to existing stations. The increased costs come not only from structural changes but also from the increased activity attracted by the rail station that may make it difficult to procure land adjacent to the rail station.

The second observation, a corollary to the first, is that the costs of some distance reduction strategies are quite small compared with the total cost of the station if they are included in the original construction of the station. Bus bays, bus ramps, escalators, elevators, off-street bus terminals, etc., are relatively inexpensive to include in stations outside the CBD. In the CBD, land may already be sufficiently expensive that such strategies are hindered to some extent.

The analysis of user satisfaction, ridership, and revenue consequences applicable to bus/bus transfers holds for bus/rail and rail/rail transfers as well, with some modifications. There is a consensus among operators that bus/bus transfers are generally more onerous than bus/rail transfers, which are in turn more onerous than rail/rail transfers. This may be due to the amenities and shelter often provided by rail facilities. If this is true, it would lower the amount of user satisfaction, ridership, and revenue gains which could be expected from reducing the associated transfer distances. However, the differences in disutility between transfer types may be partially due to the shorter headways typically found on rapid rail lines, and not on any intrinsic characteristics of rail. This would tend to reinforce the importance of reducing spatial separation for rail transfers. Indeed, the importance of the vertical transfer distance typically encountered in rail transfers to some market segments makes spatial separation a particularly important component of a rail transfer policy.

5.5 Synthesis

There exists an important tradeoff between the costs of reducing transfer walk distance and the user benefits obtained. On any particular property with its specific route and street network, the tradeoff may or may not favor reducing walk

distance. Indeed, it may be impossible in a very large city to have all routes actually intersect. Alternatively, in a small city with a well defined center, buses may naturally terminate at the same place. The purpose of this section is to relate the available strategies for dealing with transfer distance to the circumstances under which they are most applicable.

The first available strategy is to place all bus route termini in a contiguous area. For bus/bus transfers, if the transfer walk distance is less than one or two blocks, with clear lines of sight between buses, the satisfaction of transferring passengers is generally high. This is due both to the relatively short walk involved and the ease with which an infrequent user can find the connecting bus. At outlying, uncongested transfer points, buses may be placed even closer.

The key determinants of how closely a given property can come to this ideal situation for buses are the size of the CBD and the number of buses which arrive there. CBD size tends to be correlated with factors such as traffic congestion and land use intensity, both of which discourage the clustering of buses. Therefore, except in particular cases where the layout of the CBD is well suited to single-point termination, properties with large CBDs cannot generally obtain the most desirable walking distance between all buses at a single transfer point.

The number of buses which meet is also somewhat correlated with CBD size. Available information suggests strongly that the upper bound on the number of buses that can be present simultaneously at a transfer point is approximately 20. Above this number, even if all buses meet in a contiguous area, there will necessarily be a significant transfer walk distance between certain route pairs. Also, transferees will generally not have a clear line of sight between buses, reducing user satisfaction. Hence, the presence of a large number of buses leads to the need to consider other strategies for reducing transfer distance.

For bus/rail and rail/rail transfers, the most desirable situation is one where the transfer is across a platform, and where the maximum walk is approximately half the length of the train. The number of buses and number of trains which meet at one point is an important factor in determining whether this can be accomplished. More important, though, are the constraints on the construction of special facilities. Cost and availability of land and space can combine to rule out either running rail at grade, or providing the means to bring the buses to the level of the train.

It is thus often necessary to consider alternatives to the most desirable transfer distance arrangement, since so many constraining factors may be present. One possibility is an off-street terminal facility, either enclosed or outdoors. Such a facility increases the number of buses which can feasibly meet at one transfer point by bringing buses closer together than they could come on-street, simultaneously reducing street congestion and pedestrian obstacles, etc. This strategy could be used for both bus/bus and bus/rail transfers. However, such a facility may be incompatible with the current route structure, since land may not be available in a convenient location. Furthermore, on properties which most need an off-street facility, land costs can be prohibitively high. Therefore, when the tradeoff is viewed purely on the grounds of transfer distance alone, it is usually not worth providing such facilities. However, there may be site-specific, non-transfer-related reasons for building such a facility (e.g., street congestion, visual effects of many buses parked on street in the CBD, etc.).

The next several strategies are applicable mainly for bus/bus transfers, although any strategy which affects the distance between buses may also affect (indirectly) the distance between bus and rail. Bus transit malls or streets

are often a feasible alternative. The number of routes is not a constraint, because although all or most routes run down the same street, they do not all terminate or lay over at the same point in time or space. Effective spatial separation of routes is low because all buses travel past the same points. Operating cost savings may be possible if auto traffic is excluded, and capital improvements required are generally minimal. However, if the CBD is not "narrow" (e.g., four blocks or less), the implementation of bus transit malls may require significant route realignments, possibly resulting in a higher percentage of transfers downtown, and/or additional walk time for people traveling to some CBD destinations. With this restriction, the bus transit mall strategy is appropriate for any size city, and is currently employed by both large and small properties.

Another way to address the problems of bringing routes together at a single point is to restructure routes. The transfer distance between some pairs of routes can be minimized if the operator is willing to tolerate multiple transfer points. A pure grid route structure is the most extreme case, since each transfer point has only two bus routes intersecting, and spatial separation is very small between them. Subfoci represent a strategy intermediate between a grid and a single principal transfer point. However, even though these strategies avoid the problems of a single transfer point, they entail new and different tradeoffs of their own.

The subfoci strategy groups together routes which go to the same area, exchange many transfers, and/or meet at a common point (e.g. a rail station). Since the subfoci strategy implicity entails the division of bus routes into several small groups, the number of buses in each is generally not a limitation. In addition, subfoci can be easily arranged so that the CBD is well covered and transfers between routes going

to different subfoci are easily made (e.g., routes from the east side of town terminate on west side of CBD). The disadvantage of such an arrangement is extra VMT within the congested area, which leads to higher costs. This variant of the subfoci strategy can therefore not usually be implemented on a property with a large CBD without undesirable cost consequences.

With a grid system of routes, spatial separation at transfer points is minimized, number of routes is not a constraint, and coverage is maximized. This last point is especially important for properties with large central areas of high density employment and population, where a grid system is often the only appropriate route structure. A grid system, though, has some drawbacks for transferees. For example, a large number of dispersed transfer points are less comprehensible to infrequent transferees, and less secure in the evening than a small number of well-defined points. However, given that large properties may find it very difficult to bring all their routes together at one place, the cost and user satisfaction consequences associated with a grid system on such properties may make it a desirable alternative.

Additional strategies are available for facilitating bus/rail and rail/rail transfers. Escalators and elevators may be cost-effective method of reducing perceived vertical separation within rail stations themselves if included in the original construction. A bus tunnel can reduce transfer distance, but may be prohibitively costly and land-consuming in some locations, and physically impossible in others. It does, however, provide the equivalent of an off-street terminal facility and roadway which may be important in congested areas. Finally, bus bays seem to be useful in reducing horizontal bus/rail transfer distance at a relatively small cost by providing a space for more buses to meet at the rail station in a smaller area.

It is important to point out in conclusion that there is one additional major factor to consider when assessing the tradeoffs involved in reducing spatial separation at transfer points. The analysis in this section has examined the reduction of spatial separation as an independent option. In practice it is often considered in conjunction with options <u>requiring</u> physical proximity of connecting vehicles (e.g., through-routing, schedule coordination, timed transfers). Thus, while reducing spatial separation has its costs, it may also have benefits which go beyond those of the single transfer policy component standing alone, since it enhances the feasibility of other potentially beneficial options that are discussed in the following chapters.

Chapter 6
THROUGH-ROUTING

6.1 Introduction

Through-routing is the second transfer policy component to be considered in detail in this report. Through-routing, also known as interlining, is a procedure in which two routes are linked so that the same vehicle travels on both routes. It can eliminate transfers between two routes since a passenger can board a vehicle at a stop on one route and debark at a stop on another route without having to switch vehicles. Hence, through-routing is an important transfer policy option.

Also considered in this chapter is route consolidation, or the turnback of bus routes at rail stations. This option is the "reverse" of through-routing, since transfers are induced instead of being eliminated. The purpose of route consolidation is to save bus miles and hours on routes which are parallel to rail lines. Route consolidation forms an integral part of the transfer policy of many rail properties, and as such is an important option to consider.

Section 6.2 outlines the operator actions associated with several different types of bus through-routing. Section 6.2 also notes the characteristics of properties which use each type of through-routing strategy. Section 6.3 focuses on how rail properties currently do or do not utilize route consolidation. Section 6.4 examines the consequences of through-routing and route consolidation, while Section 6.5 summarizes and synthesizes the results from the previous sections. Criteria are suggested for choosing a through-routing strategy to attain operational versus ridership goals, and the tradeoffs between satisfying these two goals are outlined. Situations in which route consolidation might be productive are also noted.

6.2 Current Practice -- Bus

There is no consistent practice among U.S. transit properties regarding bus through-routing. Some properties do not route through at all, while others interline at least a few routes. At the extreme, there are some properties which use through-routing extensively. As may be seen in Figure 6-1, there is no evidence that the degree of through-routing is correlated with size of property, use of timed transfers, or amount of transfer charge.

There are several reasons why an operator will or will not employ through-routing. Foremost among these are operational/cost considerations and ridership concerns. While both of these reasons will be analyzed later in this chapter, it has been found that large and small properties alike through-route most often for operational reasons rather than for increasing ridership or user satisfaction. This may reflect the highly tangible nature of operational problems to transit operators.

Figure 6-1

BUS THROUGH-ROUTING PRACTICES BY SEGMENTATION CELL

Properties Which Do Not Use Timed Transfers Extensively

Transfer Charge	Small Size	Large Size
Full	Lawrence[1] Jacksonville[3]	Boston[2]
Reduced	Providence[3] Toledo[2] Knoxville[1]	Memphis[1] Pittsburgh[3]
Zero	Charleston[1] Duluth[1] Hartford[2] Greenfield[3]	San Francisco[2] Albany[2] Washington[3]

Properties Which Use Timed Transfers Extensively

Transfer Charge	Small Size	Large Size
Full		
Reduced	Lafayette[1]	
Zero	Eugene[1] Everett[1] Fresno[2] Westport[3]	Portland, OR[1] Denver[2]

[1]Extensive through-routing.

[2]Partial through-routing.

[3]No through-routing.

Source: Operator interviews.

Through-routing can be usefully divided into five distinct types or strategies. Each has a different set of associated operator actions, consequences, and criteria for application. These strategies are not the only types possible, but they are the most relevant to a transfer study, and they cover the spectrum of current practice on U.S. properties.

The first type of through-routing will be called "classic" through-routing. It is the most common form of through-routing, and corresponds to what is usually meant by the term interlining. In classic through-routing, two routes share the same vehicles, so that each bus approaches the termination point on one route and exits on the other. This necessarily implies that the two routes have the same headway and terminal point, and that they are paired on a regular, semipermanent basis.

The operator makes several other decisions when implementing classic through-routing. The two routes may have the same number (with other distinguishing features, such as colors) or different numbers. Through-routing can be noted on the schedule, or not. If passengers are allowed to ride through, then the operator must establish a fare structure. Through-riding can either be free, cost full fare, or cost the same as regular transferring. The first two alternatives may raise equity problems, while the third entails issuing transfer slips and then collecting them at the route-switch point or upon exiting.

Classic through-routing is used by the great majority of properties which use through-routing. The termination points for the through-routed lines are usually in the CBD, though routes may also be joined at an outlying terminus. The paired routes are usually aligned so that a passenger riding through is traveling in approximately the same direction. However,

there are some properties where this is not the case. Within the strategy of classic through-routing, therefore, there are a large number of possible variations.

The second type of through-routing can be called "single-route" through-routing. Single-route through-routing differs from classic through-routing only in that the two halves of the route are joined on a permanent basis, and formally treated as a single route. From a short-term operational perspective, single-route through-routing is the same as classic through-routing. However, user attitudes and long-term operational considerations may differ. A single-route through-route is sometimes hard to distinguish from an ordinary route. The primary identifying feature is that the single-route through-route runs through a point which would ordinarily be a terminus, such as the CBD or an outlying rail station.

A third kind of through-routing is "variable" through-routing. This occurs when buses coming off one route may be interlined to any one of a number of different routes. This type of interlining may vary throughout the day. The operator actions needed to implement this variant include extensive and potentially difficult scheduling to ensure that all routes are supplied with buses. It is not necessary that all headways match on all routes, and variations in headways on each route within a certain range are likely to occur.

The fourth variant of through-routing is the "tripper," a bus which is routed through at particular times of the day. This usually is done during rush hour, or to meet shift or school times. The operator must either add extra buses, or extend normal runs of regular routes to provide trippers. In the first case, as long as there are enough buses available, no significant interference with the rest of the system should occur. In the second case, adequate lay-over time on the

original route or a change in schedule may be needed to accommodate the tripper. It should be pointed out that a tripper will usually travel only part of the second route, perhaps only a very small part. This tends to minimize scheduling problems. A variety of properties utilize trippers, and frequently cite user satisfaction as the reason for this form of through-routing.

The fifth and final variant of through-routing will be termed "overlap." Overlap involves terminating a route on the opposite side of the CBD from which it came in. For instance, if a route comes from the east side of the CBD it would terminate just on the west side. This type of overlap is related to the subfoci strategy described in Chapter 5 for reducing spatial separation at transfer points.

Overlap is included as a variant of through-routing because it is done for many of the same operational reasons and because it can serve many of the same transfer-related purposes. In particular, overlap may eliminate the need for some distributor/feeder transfers downtown. Operator actions needed to implement overlap include disconnecting through-routed lines, and extending their lengths to move their termination points outside of the CBD.

Examples of cities which use each of these five types of through-routing are presented in Figure 6-2.

6.3 Current Practice -- Bus/Rail

Through-routing is widely practiced in the case of bus/bus transfers, but its applicability in the bus/rail case is constrained by hardware limitations. In theory, a bus could be driven over a street-based route, and then, using a second set of (steel) wheels, traverse some line-haul rail segment. To

Figure 6-2

EXAMPLES OF CITIES USING VARIOUS BUS THROUGH-ROUTING STRATEGIES

Strategy	Example
Classic through-routing	Lafayette Memphis Toledo
Single-route through-routing	Columbus Indianapolis
Variable through-routing	Everett Duluth
Tripper	Greenfield Fresno
Overlap	Baltimore

Source: Operator interviews.

date, conventional street buses have not been adapted for rail use on a widespread basis. Therefore, "dual-mode" operation will not be considered further here.

The most significant option of this type relevant to rail transfers is route consolidation. Route consolidation is the exact opposite of through-routing in that it entails the turning back at rail stations of bus routes which formerly traveled into the CBD. Route consolidation thus forces riders to transfer by making the rail lines the only transit access route into the CBD.

Several cities use route consolidation extensively and turn back all or almost all of their buses at rail stations (see Figure 6-3). Included in these are Boston, Washington, and Atlanta. Boston currently has few local bus routes which run into the CBD, while Washington turns back bus routes at rail stations wherever possible, meaning that some trips which formerly could be accomplished on one bus now require bus and rail, and sometimes even bus/rail/bus. In Atlanta, once rail service is operating at a high enough level of reliability, bus routes will be restructured to eliminate through-routes and provide feeder service to the rail stations.

In some cities, route consolidation is not used to any significant degree. New York and Philadelphia have many bus routes which run parallel to rail lines over long distances. In addition, express bus lines often parallel commuter rail lines while providing a comparable level of service (e.g., Boston, Detroit). Those cities which do not use route consolidation find that people prefer to stay on buses rather than transfer to trains trains and/or use buses for local service between rail stops. Route consolidation is typically implemented for cost reasons, and to encourage rail riding.

Figure 6-3

USE OF ROUTE CONSOLIDATION
(By Sample Cities)

<u>Use Route Consolidation</u>

Boston
Atlanta
Washington

<u>Do Not Use Route Consolidation</u>

Detroit (commuter rail)

Boston (commuter rail)
Philadelphia
New York City

6.4 Consequences

Of the five variants of bus through-routing described above, classic through-routing is by far the most widely utilized. Therefore, its consequences will be presented in detail, with the consequences of the other variants being described only as they differ from those of the classic through-routing option. A separate subsection presents the consequences of route consolidation at rail stations.

Bus Transfers

Costs

A major operational and cost consequence of classic through-routing (hereafter referred to simply as through-routing) is usually the elimination of at least some turn-around time, distance, and street space consumption. Only if all buses already stop on a one-way street or come into the CBD from the same general direction will such consequences fail to materialize.

As a result of eliminating some turn-around, VMT and VHT will usually decrease, particularly when turn-around would have occurred in a congested downtown area. This leads to a decrease in operating costs. If there is no reduction of headways, then by reducing turn-around, fewer buses may be needed on the paired routes. This cuts costs for any given level of service. For instance, when Portland, Maine eliminated downtown circling in 1976, the estimated annual operating cost savings was approximately $15,000.

Through-routing can also increase costs if it is necessary to extend the routes so that they coterminate, or reduce the headways of one route to provide a frequency match. The net

effect of through-routing on costs is therefore determined largely by site-specific factors.

A hypothetical example may help clarify cost issues. Suppose there are two routes extending in opposite directions, both of which have half-hour headways and total run times (including layovers) from 6:00 a.m. to 9:00 p.m. Suppose also that each bus turns around by circling one block, and that turning around takes approximately three minutes. Assuming an operating cost of $20 per bus-hour, if through-routing is implemented and the turn-arounds are eliminated, then the approximate annual operating cost savings are $18,000.

Continuing this very simplified hypothetical example, consider the case where one of the routes originally had a headway and run time of 45 minutes, and one bus had to be added to match the headway of the other route. The cost savings due to eliminating turn-around would be $15,000, but the cost of running the extra bus would be approximately $90,000. Clearly, any significant reduction in headways can more than offset the cost savings from through-routing (though it may also produce significant non-transfer-related benefits).

It should be emphasized that there are other factors which help determine the cost consequences of through-routing. Through-routing can aid in the logical scheduling of buses, because the operator can combine routes so that run times (including layovers) on a single route do not have to be evenly divisible by headways. This relaxes the constraints of clockface scheduling, and allows the elimination of some unproductive layover time to maintain such a schedule in the absence of through-routing.

Another factor which must be taken into account is the effect of through-routing on reliability. There is a widespread theory that through-routing decreases reliability. However, this is only true if existing mid-point layovers are

eliminated when the through-route is created. If, before through-routing, there existed sufficient layover time to absorb the unreliability of the separated routes, then the reliability of the combined route generally cannot decrease.[1] The only problem arises if one route consistently comes in late, so that even when layovers are taken into account, the reliability of the other route will be reduced as well. Extra layover time might be needed in this case (whether or not through-routing is implemented).

Conversely, routes which consistently have long layovers because of a "short" running time may be paired up with routes with "long" running times. In this way, the bus which runs late on the "long" route can make up time on the other route. In general, the presence of "slack" time in each run's layover should permit a reduction in overall layover without decreasing schedule adherence as long as delays on the two routes are not perfectly correlated.

User Satisfaction

Another consequence of through-routing which must be considered is the effect on people who transfer between two routes or would through-ride if a transfer were not necessary. The people who would benefit most from through-routing are those who most dislike the movement between buses involved in transferring. Through-routing thus affects many of the same types of people who are affected by reducing transfer distance, such as the elderly and shoppers. Of course, other user groups

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[1] It is commonly believed that mid-point layovers "must" be eliminated when through-routes are created. However, when those layovers serve a productive purpose (e.g., to enhance reliability), it may be more beneficial to retain them, though the benefits for transferring passengers are reduced.

will also benefit from the decrease in transfer walk distance and time (see Chapter 5) associated with through-routing. (Note: "transfer" time is nonzero if mid-route layovers are retained.)

People who use the paired routes but do not transfer will be affected primarily by the changes in service frequency and reliability which may accompany through-routing. Depending upon the magnitudes of these changes, general user satisfaction can increase or decrease. Most operators favor increasing service frequency to implement through-routing, thus increasing satisfaction even for nontransferees. Moreover, except in cases where a very unreliable route is joined to a previously reliable one, the reliability of the through-routed lines should not go down. Hence, in most cases, user satisfaction among nontransferring riders will not drop.

Ridership

The change in ridership due to through-routing is difficult to quantify. As explained in Chapter 4, since through-riders do not usually use transfer slips, their numbers are difficult to measure. Moreover, operators of properties which through-route for operational and cost reasons may be aware that some people are through-riding without knowing their exact number.

As would be expected, the number of through-riders on properties which through-route for ridership reasons tends to be higher than on properties which through-route for operational purposes. Based on limited data, indications are that when properties design their through-routes around travel patterns, the expected increase in ridership will not exceed 7 or 8 percent and may be even lower. For instance, before 1975 (when timed transfers were instituted), Brockton, Massachusetts through-routed for ridership purposes by connecting several routes which served logical origin/destination pairs. As a

result, 50 of 2,000 system passengers rode through each day (2.5 percent of all riders -- higher for the routes that were through-routed), and at least some of these riders would have ridden transit and transferred in the absence of through-routing. For properties that through-route for operational reasons, the number of new riders would be smaller. It would also take longer to reach equilibrium, since properties which through route for operational reasons often do not publicize the through-routing for fear that it would limit their flexibility to switch route pairs if circumstances changed.

It is possible to estimate the ridership increase from through-routing through use of demand elasticities. Assuming a transit demand elasticity for out-of-vehicle time of -0.7[1] an average door-to-door out-of-vehicle time of 30 minutes, and an average out-of-vehicle time spent transferring of 15 minutes, through-routing would increase the number of passengers who go from the first route to the second route by approximately 35 percent (.7 x .5) as long as there are no layovers at the central point. If the passengers who previously transferred from the first route to the second route made up 20 percent of the total ridership on the first route, through-riding would increase the total ridership of the first route by about 7 percent. This example tends to confirm that through-routing will have relatively small effects on ridership in most circumstances.

Revenue

The impacts of through-routing on revenue are difficult to generalize. If the fare imposed on those people who ride through is lower than that paid to transfer, through-riding may have a negative impact on revenue. However, if through-riding

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[1]Domencich, Kraft, and Valette, op. cit.

attracts new riders on a previously free transfer, then it may raise revenue. The amount of revenue depends, of course, on the number of additional riders and their characteristics. Some riders, such as the elderly, may pay a lower fare and thus have a smaller impact on revenue.

The example of ridership consequences previously presented can be used to estimate revenue consequences as well under several different scenarios. If the transfer charge previously was zero, and all new riders are paying full fare (e.g., $.50), the revenue increase on the route should be the same as the overall ridership increase, or 7 percent. If there is a transfer charge (e.g., $.10, or .2 times the basic fare) and through-riding passengers must pay it, then the revenue increase will be on the order of 8.4 percent (e.g., 7 percent x 1.2 times the basic fare) from the routes which were paired. If the transfer charge were eliminated for through-riding passengers, a revenue loss would result.

Consequences of Other Through-Routing Options

Single-route through-routing has basically the same consequences as classic through-routing, with three important exceptions. First, because the system is more easily comprehensible, there is an increase in user satisfaction to people who ride through and have greater certainty that the bus is going to their destination. This leads to possible increases in ridership and revenue. Second, because the frequencies and running times of the two halves cannot be varied independently, there is a decrease in operational flexibility. If ridership patterns change, this can have a negative effect on cost and efficiency. Finally, because the two halves are perceived as being permanently joined by users, if they are unlinked this can have a greater negative impact on

user satisfaction than would a similar unlinking in the case of classic through-routing. This can have a negative effect on ridership, revenue, and user attitudes toward transit.

Variable through-routing also has most of the same consequences as ordinary through-routing. It yields more schedule flexibility and operating cost savings than ordinary through-routing, but at the cost of making it harder to maintain constant headway on routes. In general, user satisfaction for those trips which must take place at specific times, such as work trips or school trips, will not be affected, because these people cannot wait for a particular through-routed run. However, user satisfaction is generally increased for those people who do not have to travel at a specific time, such as the elderly and to some degree, shoppers. Indeed, on at least one property (Everett, Washington) even though variable through-routing is not publicized in the schedules, elderly riders often call to ask when two particular routes will be through-routed so they do not have to transfer. In general, therefore, ridership may be increased somewhat through use of variable through-routing.

Trippers usually increase costs, since more buses and more labor are being utilized. User satisfaction will increase due to the elimination of transfers. Other riders and merchants at transfer points may also experience an increase in satisfaction, particularly if the tripper is run to accommodate sudden surges in demand (e.g., by rowdy school children). Ridership and revenue may increase from work trips, but not from school children, who tend to be captive riders.

Overlap has several consequences which are distinctly different from those of classic through-routing. As stated in the previous section, overlap is a through-routing substitute for passengers with destinations in a spread out or large CBD.

Baltimore, for instance, studied through-riders on a particular line and discovered that overlap took care of most of them. Overlap also increases operational flexibility, and allows adjustment of running times over the day and increases in the overall frequency of buses in the CBD. On the other hand, overlap increases costs by adding VMT and VHT. Moving from through-routing to overlap on one major line in Baltimore increased the number of buses required by five.

Overlap also increases the satisfaction of people traveling but not transferring in the CBD by increasing overall frequency of buses as well as CBD coverage. The ridership impacts of overlap follow from the user satisfaction effects. However, the increase in ridership due to higher frequency may dominate the transfer effect.

Rail Transfers

Costs

Route consolidation at bus/rail transfer points can have a strong beneficial effect on cost, since bus miles and hours are reduced, almost by definition. Moreover, since the miles eliminated are likely to be in the most congested areas, the cost savings are increased. Turnaround mileage, though not eliminated (in contrast to classic through-routing), is moved well out of the most congested areas, thus providing a further cut in VHT.

A reasonable estimate of the order of magnitude of cost savings can be obtained by means of a simple example. Consider a bus route over which a single bus runs on a half-hour headway from 6:00 a.m. to 9:00 p.m. Suppose the bus is supplanted over three miles of its length by a rail line. If the average speed of the bus over those three miles was 15 m.p.h., then approximately 12 bus-hours will be saved per day, or

approximately 3,600 bus-hours per year, so long as the bus and driver can be utilized elsewhere during this intermittent "free" time (e.g., using interlining). Assuming an operating cost of $20 per bus-hour, route consolidation would save $72,000 on that bus route alone. Since route consolidation typically affects a large number of routes, it is clear that this option has considerable potential for cost savings.

User Satisfaction

User satisfaction is affected by route consolidation in several ways. On the negative side it requires a transfer where none existed before, and forces individuals who might prefer at-grade buses (such as the elderly) to use rail. On the positive side, bus-to-rail transfers are generally perceived to be less onerous than bus-to-bus transfers and average trip time may be reduced if rail service is faster than the bus.

In an important sense, route consolidation must decrease "average" user satisfaction because in the absence of bus turnbacks, the rider formerly had the option of transferring at the rail station. However, the pivotal factor in determining whether user satisfaction is significantly decreased is the quality and reliability of the rail line. In Philadelphia, for instance, one subway line carries 110,000 passengers per day, while a parallel bus line carries 55,000. Despite the higher speed and fewer stops on the rail line, many people choose to take the bus. The transit authority in Philadelphia (SEPTA) is unable to eliminate parallel service and save money because of this sentiment. On systems in other cities, such as Washington, riders seem not to mind the transfer because of the comparatively high quality of rail service.

Ridership and Revenue

It is difficult to determine the effects of route consolidation on ridership and revenue. If the alternatives are parallel bus and rail lines, route consolidation can only lose passengers who would take the bus, but not bus and rail (with a transfer). Given the lower disutility of bus/rail transfers in comparison with bus/bus transfers, and the fact that some properties which terminate bus routes at rail stations have high "forced" bus-to-rail transfer rates (e.g., between 70 and 80 percent at some stations), it does not appear that route consolidation discourages much ridership. However, the fact that certain market segments (e.g., elderly, handicapped, and shoppers), may be disproportionately burdened by the vertical distance involved in forced bus/rail transfers makes it difficult to generalize on such estimates.

6.5 Synthesis

Bus through-routing can be used for two distinctly different primary reasons -- reducing operational costs or increasing user satisfaction. Criteria have therefore been developed which correspond to each of these major motivating factors. The criteria focus on settings where various through-routing strategies should be considered, though they obviously cannot cover all site-specific factors which may influence an operator's final decision. Criteria for implementing route consolidation on rail properties have also been developed.

Criteria for Bus Through-Routing

Bus through-routing can have a significant impact on both operating costs and ridership. The major cost savings from through-routing are due to the elimination of turnaround time

and distance. These savings will be greatest in areas where there is significant congestion and/or the pattern of streets requires lengthy turnarounds. The savings will be smallest in cities where buses have to turn around anyway, either because all buses travel on a one-way street (e.g., Lafayette, Indiana), or where the CBD is at the edge of the service area (e.g., Jacksonville, Florida). Thus, substantial cost savings are most likely to accrue in cities with a congested CBD in which routes enter from more than one direction.

The major potential cost disadvantage from through-routing is associated with the need to match headways. This is most important on properties where political or demand constraints rule out reducing the frequency of service. It should be noted that properties which use uniform clockface scheduling or timed transfers will already have matched headways, so through-routing will have little negative cost impact.

One major operational advantage of through-routing is that it diminishes the constraints on "logical" scheduling. On some properties, routes may have "natural" lengths (due to the structure of the service area or population location) and "natural" headways (due to demand) such that the running time (with layovers) is not evenly divisible by the headway. Through-routing can provide a solution to this problem by combining routes to make total running times divisible by the logical headways and increase productivity and efficiency by elimination of unproductive runs or layovers. This use of through-routing is most applicable when properties are constrained by service area boundaries, or when operators seek to maintain clockface or pulse scheduling.

A second operational advantage of through-routing is the gain in reliability which occurs when all original mid-point

layovers are retained in the schedule and used to "cross-subsidize" schedule adherence between routes. This is most likely to occur when the connected routes traverse areas which are physically separate and have different characteristics (e.g., land use), so that a single perturbation (e.g., traffic congestion) does not cause both routes simultaneously to require additional layover time.

Through-routing also has some operational disadvantages. Scheduling is somewhat more difficult with through-routing (although it should be noted that several versions of RUCUS naturally yield extensive interlining). The service area affected by schedule unreliability can increase if not enough layover time is available on the two routes, since one route which is consistently late can cause the other to be late as well. This problem must be carefully considered if there are factors such as at-grade rail crossings or extreme traffic congestion which cause one route to be particularly unreliable.

It is important to note that the different variants of through-routing outlined before have different types of impacts on operations and cost. Single-route through-routing does not have much flexibility for adjusting route pairs. Variable through-routing is difficult to schedule. Trippers need less matching of headways, but cost more if level of service is to be maintained. Overlap is significantly more costly, but may have important operational advantages in cities with large CBDs.

It is also important to point out that through-routing for either operational or cost reasons need not be restricted to the CBD. Operators may through-route lines which coterminate at their outer ends, particularly in a grid or parallel service network where outer route termini are not widely separated. Also, cities with rail service and transfer points at the rail

stations may through-route for cost reasons, due to the tendency for rail stations to be situated in areas of relatively intensive surrounding land use.

It cannot be emphasized too strongly that the operational and cost consequences of through-routing are heavily dependent on the street layout and other conditions. For instance, on some properties the dominant reason for implementing through-routing might be the elimination of dangerous left turns. On other properties the relevant operational/cost considerations might be equally site-specific.

The second principal motivation for through-routing involves user satisfaction and ridership goals. The major effect of through-routing on user satisfaction comes from the elimination of transfers between two routes, and thus the elimination of waiting and walking time between buses. This tends to indicate the type of groups and situations which would benefit most from through-routing. Properties with strong and definite flows to outlying shopping malls, for instance, may want to interline the mall route with a route running through a densely populated residential area (classic through-routing). The groups tending to benefit from this would be shoppers and elderly, the groups which are most burdened by the movement associated with transferring.

Properties with periodic peak flows to particular points, on the other hand, might profitably run trippers. Also, if there is a relatively dispersed flow of passengers, variable through-routing is a possible option. This will principally benefit the elderly, or others who can afford to wait until a particular time of day for service. Properties which have a large amount of transferring to reach destinations within the CBD may consider overlap.

The principal negative impact on user satisfaction associated with through-routing comes from the increased complexity of the system. The satisfaction of transferees

cannot decrease with through-routing but any increase can be lessened by the difficulty of understanding the through-routing system. Single-route through-routing is the simplest to understand. Complexity increases from single-route through-routing to overlap, to classic through-routing, to trippers, up to variable through-routing. Informational devices such as signs on bus and notes on schedules increase potential utilization and user satisfaction. However, publicizing through-routes does lead to the possibility of user dissatisfaction and public relations difficulties if the through-routing pairs are subsequently changed.

Ridership will usually increase if through-routed pairs connect logical destinations and origins, and if the public is aware of the connection. The increase in ridership depends entirely on site-specific factors, and may be as much as 7 percent on the paired lines.

It is possible for ridership not to increase with through-routing, especially if the through-routed pairs are not publicized, and logical origins and destinations are not connected. This tends to occur when through-routing is done for operational rather than ridership reasons. However, there are almost always some through-riders on any pair of lines. If through-routed pairs are changed, ridership will usually go down, at least in the short run. Properties which through-route for operational reasons may wish to maintain particular through-route pairs if they have attracted significant numbers of through-riders.

There is no reason to expect that operations/cost and user satisfaction/ridership criteria will necessarily lead to selection of different through-routing strategies in every setting. However, it is clear that the basic motivating factor plays a dominant role in the selection of through-routing policies, and the consequences which result.

Criteria for Route Consolidation

The tradeoffs involved in route consolidation are significantly simpler than those described above for through routing. The decision to implement route consolidation necessarily weighs the cost of providing parallel service against the possible decrease in user satisfaction caused by forcing people to transfer and by eliminating local service between rail stops. In some situations, this tradeoff may not be important because route consolidation is the dominant option. This will occur where the CBD and the corridor leading into CBD are so congested that bus speeds are significantly lower than rail or where rail trips are sufficiently long that even small advantages in operating speeds are translated into major time savings. In either of these two cases, a low frequency, low cost local route could be retained to service passengers traveling for short distances between rail stations.

Operating a competitive parallel bus service becomes a reasonable alternative if the rail line has a low enough frequency that lengthy transfer times are possible when transferring from bus to rail, if the rail line is unreliable, unattractive, or short in length. Under these conditions, route consolidation may significantly lower user satisfaction while reducing costs. Of course, it may be possible to apply the money saved by route consolidation to upgrading service in other parts of the system. This may raise the overall level of satisfaction enough to compensate for the drop in user satisfaction of passengers forced to transfer between bus and rail. However, this must be determined on a site-by-site basis.

This section has shown that through-routing and route consolidation are transfer policy options which can be applied in numerous settings. However, the attitudes and motivations

of the service provider, as well as numerous site-specific conditions and factors, make selection of the best configuration of through-routing or route consolidation in any particular setting a task to be undertaken with considerable care.

Chapter 7
SCHEDULE COORDINATION

7.1 Introduction

Wait time is one of the more important transfer level-of-service attributes. To the average traveler, out-of-vehicle time is typically perceived to be two to three times as onerous as in-vehicle time. Therefore, the time spent waiting for a connecting vehicle will have a large effect on user satisfaction, and hence on the ridership attracted.

There are three situations involving the timing of the transferring (first) vehicle's arrival and the arrival of the connecting vehicle which are important from the viewpoint of the transfer policy component of schedule coordination. In the first case the connecting vehicle is scheduled to be at the transfer point just before the transferring vehicle. This would generally cause passengers transferring to the connecting vehicle to have an average transfer wait just under the full headway of the connecting vehicle. In the second case the connecting vehicle is scheduled to be at the transfer point simultaneously with the transferring vehicle. Depending on the

amount of layover time (if any) and the degree of schedule adherence on the two routes, this can lead to a wait time for the passenger transferring to the connecting vehicle of from zero time up to the full headway of the connecting vehicle. The third important case is when the connecting vehicle is scheduled to be at the transfer point just after the transferring vehicle. The average wait time for a passenger transferring to the connecting vehicle would then be very low.

It is clear that a passenger transferring to the connecting vehicle would prefer the second possibility to the first, and the third possibility to the second. On the other hand, a passenger transferring in the other direction will have exactly the reverse order of preferences. For both groups the change in transfer level of service is induced wholly by a change in schedules.

Schedule coordination, as a transfer policy component, is defined as an adjustment of schedules on routes to change their relative times of arrival. It must be noted that timed transfers is a particular case of schedule coordination (see Chapter 9). Timed transfers focus on the case in which vehicles are scheduled to arrive at the same time, with additional measures taken to guarantee that the vehicles will actually be at the transfer point simultaneously. Therefore timed transfers, in contrast to simple schedule coordination, benefit passengers transferring in both directions. Used alone, schedule coordination will generally benefit passengers transferring in one direction more than passengers transferring in the other, unless schedule reliability is so high that simply scheduling vehicles to be at the same place at the same time is sufficient to ensure that they will be there. This is rarely the case unless special measures (such as adding layovers) have been taken. This option is discussed under the heading of timed transfers.

This chapter covers the practice and consequences of schedule coordination only. Section 7.2 examines the types of schedule coordination for bus/bus transfers. Section 7.3 is concerned with schedule coordination of rail/rail and bus/rail transfers, while Section 7.4 considers the consequences of schedule coordination, and Section 7.5 provides a synthesis of the results presented in the previous section. Situations where different types of schedule coordination are appropriate are discussed in this section.

7.2 Current Practice -- Bus

Bus schedule coordination generally takes one of three forms: large-scale adjustment of schedules in the CBD during peak hours, trunk-crosstown coordination, and minor schedule adjustments on connecting routes. Each form requires different operator actions, and is appropriate in different situations. Figure 7-1 shows examples of properties which use each of these.

Large-scale peak-hour CBD schedule coordination is used when there is a strong directional flow of transfers through the CBD. This tends to occur in small- to medium-sized cities where trip patterns may be strongly influenced by particular demand generators or geographic/demographic groups. For instance, one common situation is the travel of low-income domestics to work in outlying residential areas. These riders often have to transfer in the CBD, and the route-pairs involved typically generate little transferring in the opposite direction. The flow of transfers would be in one direction during the morning peak, and in the opposite direction during the afternoon peak.

While the amount of CBD schedule coordination varies from property to property, a major criterion for choosing which

Figure 7-1

EXAMPLES OF PROPERTIES USING
SCHEDULE COORDINATION STRATEGIES
FOR BUS/BUS TRANSFERS

Strategy	Property
CBD schedule coordination	Knoxville Winston-Salem Greenfield
Trunk-crosstown schedule coordination	Toledo Fresno
Minor schedule coordination	Pittsburgh Portland, ME Boston

Source: Operator interviews.

particular routes to pair is the volume of transfers (though there may not be a single threshold of transferring volume at which schedule coordination becomes viable). Properties also share a tendency to pair routes which have relatively low frequencies (generally headways of 30 minutes or more), since expected transfer time increases with connecting route headway when service is uncoordinated.

Typically, one bus is scheduled to arrive approximately five minutes before the other in the morning, with the order reversed in the afternoon. If the buses terminate in the same place and have reasonable schedule adherence, an "advance" of five minutes seems to guarantee that the passengers from the first bus will be able to catch the second. Advances of up to 10 minutes are not uncommon for routes with longer headways (e.g., 60 minutes). Poor schedule adherence may also require added margins.

The headways of the two coordinated routes do not necessarily have to be equal, if all runs of the first route need not be followed by a bus from the other route. However, the peak periods are crucial for schedule coordination, since strong directional flows occur most frequently at these times. Since headways are most often short during peak periods, particularly in the CBD, a low level of effort may be required to implement CBD schedule coordination on most runs for a given route pair.

The second type of schedule coordination, "trunk-crosstown" coordination, involves transfers between trunk lines and crosstowns instead of transfers within the CBD. Trunk-crosstown coordination is typically found on larger properties than large-scale CBD schedule coordination, since only larger properties have crosstowns, and thus the opportunity to transfer outside the CBD.

Trunk-crosstown coordination is typically not as important in the morning peak as the first type of coordination because, as a rule, the frequency on large city trunk lines is significantly higher than on crosstowns. Passengers transferring from the crosstown to the trunk line will generally not have a long wait, even under the worst of circumstances. Thus, the important direction to coordinate is the evening peak, when transferring occurs from the trunk line to the crosstown. Unlike CBD schedule coordination, trunk-crosstown coordination does not require a strong directionality of flow, since transfers in the other direction experience a low transfer time anyway.

The advance used for trunk-crosstown coordination may be less than the advance used in CBD schedule coordination because of three factors. First, the spatial separation of the routes involved is usually less at the transfer points where trunk and crosstown lines cross than in the CBD. Second, because the volume of transfers may be less than in the CBD, the time required on boarding and alighting is less. Third, and very importantly, because the routes are close together and buses can often be seen from one another over considerable distances, the crosstown bus can be instructed to hold at the transfer point if the trunk line bus is late. This third factor is actually an example of dynamic control, and will be treated in depth in Chapter 8.

There is usually no question of matching headways in trunk-crosstown schedule coordination, since the respective frequencies may differ greatly. The need, therefore, is to determine which runs of the trunk lines will be coordinated with which runs of the crosstowns. Usually the trunk line and crosstown are scheduled independently, and then must be adjusted so that selected runs will meet. However, in some instances runs have been cut with coordination in mind, so that little *ad hoc* adjustment is necessary.

Special attention must be given to the problem of multiple transfer points. Many properties have crosstowns which intersect more than one trunk line, or vice versa, creating several opportunities on the same line to coordinate schedules. One example of such multiple schedule coordination is in Kansas City, where the schedule of a single trunk line is coordinated with buses (sometimes going in both directions) on three different crosstowns in the evening; furthermore, two of the three crosstowns eventually meet the trunk line and other routes downtown in a line-up. Unfortunately, such scheduling virtuosity is not common, practical, or even always possible. Usually a choice must be made between transfer points, and the relevant criterion is the number of transfers. Schedule coordinating the crosstowns with the largest headways is not likely to be as productive, since fewer passengers will typically benefit.

Both CBD and trunk-crosstown coordination entail similar operator actions regarding publicity. Rarely is any attempt made to publicize schedule coordination beyond the printing of the schedule. Also, transfer points where schedule coordination occurs are sometimes not even time points on the published schedules. The prevailing assumption is that riders of these lines know about the coordination without special publicity. The fact that this information about transfer level-of-service improvements is not available to nonregular riders of particular lines is characteristic of many transfer components, and will be discussed in detail in Chapter 14.

The third type of schedule coordination is called "minor" schedule coordination. Characteristically, it is implemented after schedules have been put into effect, and some passengers complain that they are just missing their connection. A typical case would involve a group of workers coming off a shift who take the same bus, and then have to transfer. The

operator actions involved would be to adjust the schedule of that particular run on the connecting route so that the riders can make their bus.

Clearly, minor schedule coordination is different from the other two types. It is directed toward a particular pair of buses, rather than between two routes as a whole. As such, it occurs on properties of any size. The operator need not worry about matching headways, or publicizing the coordination. As its name implies, minor schedule coordination involves a very low level of operator effort, both in scheduling and in actual operation.

7.3 Current Practice -- Rail

Schedule coordination for bus/rail and rail/rail transfers is uncommon (compared to the number of possible opportunities). Several reasons have been cited by operators for this lack of use, the most important of which is the fact that bus and rapid rail lines typically operate at high frequencies for at least most of the day. During the day, headways in rail rapid transit systems tend to be on the order of 10 minutes or less, while headways on bus lines (for cities large enough to have rail systems) tend to be no higher than 15 minutes. These headways are sufficiently short that schedule coordination could not produce significant reductions in tranfer time (see Chapter 11). Also, in cases where the distance (vertical or horizontal) between connecting vehicles is long and/or variable (e.g., different parts of the rail platform differ significantly in their distance from the bus stop), the variance across passengers of transfer walk time may make it necessary for the "advances" needed to ensure a timely transfer between vehicles for most passengers to be longer than in the bus/bus case. Thus, the benefits which accrue through use of this option are less in the rail case.

In many rail properties, rail scheduling and bus scheduling are done in separate independent offices. This may lead to bus operators optimizing their schedules without any consideration of rail schedules. Similarly, it is difficult to institute schedule coordination when buses run by one operating authority try to meet commuter trains run by another operating authority (e.g., Westport and Conrail). In this case, changes in the commuter schedule often cause serious problems for bus schedules. Multiple intersections among bus and rail routes, and the inflexible nature of rail scheduling also make bus/rail and rail/rail schedule coordination difficult to accomplish, though they do not rule it out completely.

Figure 7-2 gives examples of different types of schedule coordination employed on rail properties. The most common form of schedule coordination is from rail rapid transit to bus at outlying rail stations in the evening. Typically, there are two or three train arrivals to each bus arrival, so not all trains are met. For instance, the bus may be on a 30-minute headway while the rail line runs every 10 minutes. In general, headways are not altered to achieve the coordination, and it is almost always the case that the bus schedule rather than the rail schedule will be adjusted. The bus is usually scheduled to leave 4 to 5 minutes after the train is scheduled to arrive, often with some sort of dynamic control to hold the bus if the train is late (see Chapter 8). The operating authority does not usually provide information concerning which trains are met by buses, or even that schedule coordination exists at all.

The next most common form of schedule coordination is between buses and commuter trains. This occurs in both the morning and the evening peak hours, with the bus arriving before the commuter train in the morning, and after the train in the evening. The buses involved are often "dedicated" to

Figure 7-2

EXAMPLES OF SCHEDULE COORDINATION ON RAIL PROPERTIES

<u>Rail-to-Bus Schedule Coordination in Evenings</u>

San Francisco
Philadelphia
Cleveland
Chicago

<u>Schedule Coordination Between Commuter Rail and Bus During Peak Hours</u>

Westport (with Conrail)
Detroit

<u>Schedule Coordination Between Intersecting Rail Lines</u>

Philadelphia

the commuter service. This is due to the relatively low frequency and low reliability of commuter rail service, which means that the buses cannot be late in the morning, and they must be prepared to hold for late commuter trains in the evening. Schedule flexibility is essential, and having regular bus routes meet the trains may therefore not be appropriate. In the morning, buses are typically scheduled to arrive at least five minutes before the train. In Westport, for example, it has been found that because commuters would rather be early than late, and because they want to buy newspapers and coffee, having buses come in 10 minutes early is acceptable. In the evening, scheduling the buses to leave five minutes after the train's arrival seems to allow passengers to reach the bus, although people are occasionally left behind. Dynamic control is almost always used, especically to ensure a meeting, with the last commuter train.

A third form of schedule coordination is between two rail vehicles on intersecting routes (as opposed to local and express routes running parallel on the same trackage). For example, the two subway lines in Philadelphia are coordinated in the off-peak and evening to facilitate transfers from west to south. This is the prevailing direction of travel, but there is a significant reverse flow of transferring passengers who must wait the full headway of the connecting routes. A light is available on one platform to tell the conductor when the other train has come in, so that dynamic control can be applied.

7.4 Consequences

Bus Transfers

CBD Schedule Coordination[1]

In order to assess the consequences of schedule coordination, it is necessary to specify both the type of coordination used and the "default" situation which would occur without its use. Large-scale CBD schedule coordination usually involves several consecutive runs on the same line and is typically implemented as schedules are being drawn up. Since headways may be adjusted slightly, there can be some cost consequences, though these are generally minor in the context of normal peak-hour operations. A large gain in user satisfaction is possible for people transferring in the "right" direction. However, user satisfaction of the few passengers traveling in the other direction may drop drastically. For any particular run it is of course possible for the normal scheduling procedures to yield a short transfer time in one direction by coincidence. Formal schedule coordination, though, allows a larger group of riders to benefit and minimizes the chance of a long wait time.

Ridership may not increase greatly with the institution of CBD schedule coordination. Since it is only used in smaller cities (which exhibit a strong directional flow of riders through the CBD), trips requiring transfers will tend to be between residential areas or to outlying employment centers. Since low-income captive riders may make up a large

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[1]Note: Since the consequences of the available strategies for schedule coordination are so different in scope and character, each strategy is assessed independently in this section.

proportion of such ridership, it is likely that service quality changes such as schedule coordination will induce few new riders. On the other hand, particular cities may exhibit latent demand for traffic through the CBD from higher-income areas. Schedule coordination may be a way of raising the level of service and attracting new riders and revenue from this market. However, there must be few people riding in the opposite direction whose level of service would be severely diminished by the implementation of schedule coordination.

A hypothetical example of the effect of CBD schedule coordination can be calculated using the transit demand elasticity with respect to out-of-vehicle time of -0.7 cited previously. Assuming 30-minute headways (and a 15-minute average transfer wait time in the absence of schedule coordination), and a total door-to-door out-of-vehicle time of 30 minutes, the implementation of schedule coordination will have the effect of decreasing transfer wait time for passengers transferring in one direction to 5 minutes (a 33 percent reduction in out-of-vehicle time) and increasing transfer wait time for the other direction to 25 minutes (a 33 percent increase in out-of-vehicle time). Schedule coordination will therefore produce a 23 percent increase in the number of passengers who transfer in the direction of coordination, and a similar decrease in the number of passengers who transfer in the opposite direction. Since CBD schedule coordination is only implemented when the transfer flow is strongly directional, there will be a net gain in total passengers.

Assuming a 25 percent transfer rate in the direction of coordination and 5 percent transfer rate in the other direction, the above example would predict an overall gain in ridership and revenue on the order of 4.5 percent. In some cases this estimate will be too high, because strongly directional transfer flows may originate in areas where much of

the population is low-income or captive, with lower demand elasticities. However, significant ridership and revenue gains have been realized through use of this option, and increases of 3 or 4 percent are reasonable to expect.

Trunk-Crosstown Coordination

The consequences of trunk-crosstown coordination depend upon many of the circumstances surrounding its implementation. If the schedules of the trunk and crosstown routes are made to interlock completely, there will be definite, though not major, impacts on cost as a result of headway adjustments. On the other hand, if particular runs are adjusted after the schedules are drawn, the cost consequences will be quite small, depending on the size of adjustment. It should also be pointed out that if trunk-crosstown coordination is done at multiple transfer points on the same line, system schedules would normally be designed with that intention, rather than adjusted on an ad hoc basis.

User satisfaction will increase for those (outbound) riders traveling from the trunk line to the crosstown, reaching a maximum if they know what bus to take to arrive just before the crosstown. More importantly, trunk-crosstown has a low disutility for reverse riders, due to the typically high frequency of service on trunk lines. Of course, if the trunk line frequency is not sufficiently high (e.g., every 10 minutes), the directionality of flow from trunk to crosstown must be more pronounced in order to make schedule coordination worthwhile.

Ridership can be expected to increase with trunk-crosstown coordination for two reasons. First, trunk-crosstown coordination eliminates the longest of the transfer waits without the transferring rider needing to know anything about the schedule. With very long headways, this improvement may be substantial and induce additional ridership, since

trunk-crosstown transfer points are usually more isolated and provide less shelter than CBD transfer points. However, all of the attractive powers of trunk-crosstown schedule coordination are not used unless riders and potential riders are made aware of the possibility of cutting down the transfer time to near-zero by taking the right bus. Revenue, of course, will follow ridership. A rough estimate of the revenue and ridership change attributable to trunk-crosstown schedule coordination would be half of the 3 to 4 percent change calculated in the hypothetical example for CBD schedule coordination. (The factor of one half is used because trunk-crosstown schedule coordination is only applied in one direction.)

Minor Schedule Coordination

Minor schedule coordination has almost no cost consequences at all, since it typically involves only slight schedule adjustments of a particular run in response to user complaints. The increase of user satisfaction for the riders who previously were just missing their bus is liable to be substantial, especially where there are long headways on the connecting bus. However, because the increase in user satisfaction is restricted to a particular run, there is not necessarily any significant direct gain in ridership or revenue. Nevertheless, this type of response of the service provider to user complaints may be a particularly valuable type of marketing tool to produce longer-run changes in consumer attitudes and ridership (see Chapter 15).

Rail Transfers

Rail-to-Bus Schedule Coordination

The consequences of rail-to-bus schedule coordination are very much like those of trunk-crosstown bus schedule

coordination. If headway changes are not made, the operating cost of the schedule adjustments needed to implement rail-to-bus schedule coordination will be quite small. On the other hand, the administrative cost and effort may be greater than in the case of bus schedule coordination because the bus schedule maker may not normally work with the rail schedule maker.

User satisfaction, ridership, and revenue will increase with rail-to-bus schedule coordination for the same reasons which apply to trunk-crosstown schedule coordination (see above). The exact magnitude of such increases cannot be calculated, but a 2 to 3 percent increase in ridership during the period when the coordination is in effect would not be unreasonable to expect. This estimate is consistent with the opinions of several rail operators.

Schedule Coordination between Commuter Rail and Bus

The costs (both operating and administrative) of providing commuter rail/bus schedule coordination are greater than the costs of rail-to-bus coordination. Administratively, the bus schedule makers must be responsive to rail schedules which are often created by a completely different operating authority. Moreover, the buses must meet particular trains. In terms of operating cost, commuter rail/bus coordination seems to require bus runs which are devoted to meeting the commuter rail in order to guarantee connections. This generally means adding more service, which adds more cost. However, commuter train arrivals and departures in outlying towns may fall outside of the peak hour for trips within the town. Hence, providing bus connections does not necessarily increase the peak number of buses needed and, depending on the labor contract, provisions, etc., may not cost as much as adding peak-hour service.

The satisfaction of feeder bus users should increase significantly with schedule coordination. However, the magnitude of ridership and revenue increases attributable to schedule coordination is uncertain. For example, in Westport, out of 2,400 commuters that board Conrail trains, buses carry about 400 to 500 inbound in the morning, and 500 to 600 outbound in the evening. This imbalance is at least partly caused by commuters having a disproportionate preference for high-speed access in the morning (New York is a considerable distance away and personal schedules are often tight), and finding the bus easier than having someone pick them up in the evening. The known presence of factors such as these in the modal selection process makes it difficult to reliably attribute ridership changes to bus/commuter rail schedule coordination on the basis of current data.

<u>Schedule Coordination between Intersecting Rail Lines</u>

The cost consequences of rail/rail schedule coordination appear to be small, since at least rapid rail typically runs relatively frequently, even during the off-peak and evening periods when this option is most productive. User satisfaction for riders traveling in the direction of coordination will go up, but once again, if rail/rail transfers are not onerous due to the short headways, the increase will not be large. Similarly, the user satisfaction of riders traveling against the direction of coordination will go down as average wait time goes up, but this change may also not be important. Ridership and revenue can be expected to be affected, but unless conditions in the rail station are such that transfer wait time is truly onerous, the drop in average wait time from, say, 7 to 4 minutes will not attract many new riders.

7.5 Synthesis

If transfers are strongly directional between two lines at any time of the day, and if a reasonable degree of schedule reliability exists, schedule coordination may be very productive for the operator to undertake. It typically costs little and demands almost no real-time operator attention. Because user satisfaction for the (assumed) large proportion of people transferring in the correct direction is increased as their average transfer time is decreased, ridership will be induced in most cases. Schedule coordination therefore may be a very cost-effective way to improve service.

However, there are definite limitations on when most types of schedule coordination can be applied. The major restriction is the need for strong directionality of transfers. People transferring in the "wrong" direction will generally have a transfer wait equal to the entire headway (minus the advance) of their connecting bus; from the point of view of ridership, equity, and public relations, this may be unacceptable if a sizable number of people are affected.

The result is that schedule coordination is inapplicable in many situations. For instance, it is largely inappropriate for daytime off-peak usage, since off-peak traffic is not nearly so strongly directional. More important, it cannot be used in the CBD unless there is a skewed distribution of origins and destinations. Since this is a condition which is much more likely to occur in small cities than large ones, city size is a determinant of the applicability of schedule coordination.

Each of the three types of bus schedule coordination and three types of rail schedule coordination has its own areas of applicability. CBD bus schedule coordination can profitably be used in cases where a definite peak directional flow of passengers from one area of a city to another passes through

the CBD. In such cases, CBD schedule coordination can improve the level of service without significantly increasing costs.

Trunk-crosstown bus coordination may be more widely applicable than large-scale CBD coordination, since its effects are less sensitive to the directionality of the transfer flow. The typically high frequency of the trunk line has already been mentioned as a mitigating factor. Furthermore, the fact that there are generally two crosstown buses on each route (one in each direction) which intersect the trunk line increases the operator's flexibility to "tailor" the coordination to actual transfer flow patterns. (Note, however, that this may produce second-order run-cutting problems on the crosstown route.)

Trunk-crosstown bus schedule coordination is therefore not restricted to highly directional situations. It does seem most useful when the crosstown has a long headway, so that excessive transfer wait times for people transferring from the trunk to the crosstown are eliminated. However, trunk-crosstown schedule coordination may be difficult to implement on a complex system, since adjustments of schedules at one transfer point may cause people riding the bus to miss their connection at another. A possible solution to this problem is to approach scheduling from more of a network perspective, altering headways and layovers to facilitate more widespread use of schedule coordination.

Minor bus schedule coordination can be implemented on virtually any property at any time of the day. The easiest and most common procedure for determining where to make such adjustments is to simply respond to complaints. This method generally uncovers the worst trouble spots, though it may miss cases which are so bad that no one rides (and hence no one complains), or where infrequent users, who have a low level of awareness of or interest in system operations, make up the bulk of transferees. Surveys or interviews of some sort may

therefore be needed to supplement the user-complaint approach typically employed.

Rail-to-bus schedule coordination is appropriate in the evening at outlying transfer points, where the frequency on the connecting bus line is relatively low and the rail lines operate with reliable schedules. Commuter rail/bus coordination can be used profitably in many suburban communities when there is sufficient demand for transit to the trains to warrant separate bus service. The third type of rail schedule coordination, rail/rail coordination, can be applied at transfer points where the transfer flow is at least somewhat directional and the rail lines are not widely separated spatially.

In summary, schedule coordination may be a very cost-effective course of action, especially in situations where transfers are highly directional. Schedule coordination may be applied either systematically at major transfer points, or in response to isolated passenger complaints. Schedule coordination also is an important element of timed transfers, a transfer policy component whose consequences can be far reaching. Schedule coordination is thus an important transfer policy component.

Chapter 8
DYNAMIC CONTROL

8.1 Introduction

A vehicle can be held beyond its scheduled departure time from a transfer point if it is known that a vehicle on another route which is likely to have transferring customers on board is approaching. Such information can be conveyed by radio or by some other signaling device (e.g., blinking lights). Because real-time modification of operations are required, the transfer policy component corresponding to these actions will be referred to as dynamic control.

Dynamic control, as a transfer policy component, can be distinguished from schedule adjustments (such as schedule coordination) by its contingent nature. Dynamic control does not involve the *a priori* changes in schedules of schedule coordination. Instead, the utilization of dynamic control depends on two factors. First, there must be people who want to transfer from one *particular* vehicle to another (although this element may be assumed in the case of transfers from rail vehicles). Second, the vehicles must arrive at the transfer

point within a short enough interval that holding the first arriving vehicle (which is receiving the transferees) does not unduly perturb the rest of the system.

Theoretically at least, dynamic control can stand alone as a transfer policy. In practice, however, dynamic control may be most frequently employed in conjunction with schedule coordination or timed transfers, since vehicles are scheduled to arrive within a small time interval with both of those options and schedule overlapping is clearly an objective at these properties. Section 8.2 examines current use of dynamic control of bus/bus transfers from several perspectives: actual use of dynamic control alone, the theoretical possibilities of dynamic control, and dynamic control in conjunction with scheduling options. Section 8.3 describes current use of dynamic control of transfers involving rail vehicles.

Section 8.4 describes the operational and user consequences of dynamic control, while Section 8.5 outlines criteria for applying dynamic control to different situations. Like the previous sections, this section outlines interactions between dynamic control and other components.

8.2 Current Practice -- Bus

Use of some form of dynamic control for bus/bus transfers is currently widespread. Figure 8-1 lists examples of properties using dynamic control in conjunction with timed transfers, and properties using dynamic control alone. Particularly among smaller properties employing timed transfers, dynamic control is used regularly to ensure that a significant proportion of buses meet. It must be emphasized that timed transfers are the more important component of this combination in terms of operator effort. However, dynamic control, by guaranteeing that buses will actually meet in a timed transfer, is an important factor in attracting ridership (Chapter 9 examines this in detail).

Figure 8-1

EXAMPLES OF PROPERTIES USING DYNAMIC CONTROL

Type of Dynamic Control	Property
Dynamic control alone	Portland, ME Toledo Cleveland Indianapolis
Dynamic control with timed transfers or schedule coordination	Brockton Lafayette Knoxville Haverhill Eugene Memphis Fresno

Source: Operator interviews.

Almost all of the properties which use timed transfers extensively (i.e., pulse scheduling at major transfer points all day), use dynamic control. Most have radios by which late buses can call ahead and inform the waiting buses which, if any, will be receiving passengers. Either the dispatcher or starter (or perhaps the individual drivers) can then release the buses which would not be receiving transferees and hold the others for the late bus. The typical maximum holding time is 5 minutes. Given that most of these properties pulse every half hour, holding buses longer would severely interfere with the next pulse. In addition to the role as a complement to other transfer policy options, several small properties use extensive dynamic control alone, either to control meetings between trunk and crosstown routes or occasionally to facilitate transfers in CBDs when the schedule permits.

A particularly interesting application of dynamic control as a stand-alone option occurs in circumstances where schedule adherence is poor. In this case, the driver of a bus with transferring passengers can ask the dispatcher if there is a connecting bus at the transfer point. If there is, then it can be held for the transferring passengers. This type of dynamic control is used in Portland, Maine, where winter storms sometimes reduce schedule reliability. Dynamic control then helps to ensure that buses will meet at transfer points, without fear of perturbing an already perturbed system.

Many properties use dynamic control either on a few routes or in the evening. These properties tend to be significantly larger than those which make more extensive use of dynamic control. Again, those properties which make marginal use of dynamic control often combine it with either timed transfers (in the form of line-ups) or schedule coordination. In addition, there are some properties which use dynamic control by itself as a substitute for either trunk-crosstown or minor

schedule coordination in cases where people are just missing a connecting bus. The difference between schedule coordination and dynamic control in these situations lies in the amount of real-time operator action needed. Once schedules are coordinated, the bus normally makes the same connection every day without any other operator input. This implies that the bus will follow the revised schedule even when there are no passengers wanting to transfer to it. With dynamic control, on the other hand, the connecting bus will wait only if it is to receive transferring passengers.

There are differences in implementation procedures between small properties which use dynamic control extensively, and large properties which use it marginally. Extensive users generally employ radios to signal the connecting bus to wait. Drivers of connecting buses are typically instructed to hold up to two to three minutes for the first bus, contingent upon being able to make up running time. This restriction may limit the use of dynamic control during peak hours of traffic congestion, or when the connecting bus is running late.

Another type of communications procedure, which does not involve radios, can be utilized on any type of property. It consists of a driver at a transfer point looking to see if another bus is coming, and holding if one is. In another version, the oncoming bus flashes its headlights if there are passengers on-board who want to transfer. On large properties with many buses, this approach may be restricted to particular situations, since indiscriminate use could cause schedules to degenerate quickly. Such "eyeball control" is often used as a supplement to the other types of dynamic control.

Several dynamic control methods are technologically possible and potentially useful, though their use is not widespread at this time. These involve various versions of automatic vehicle monitoring (AVM) and simple sensor

systems. The sensor system could be similar to the one used for bus-actuated traffic signals, allowing an oncoming bus to actuate a signal at the transfer point. Other technological arrangements can be imagined, but the lack of current implementations makes it impossible at this time to draw useful conclusions concerning their applicability or consequences.

Dynamic control is used by small properties at almost any intersection of routes, except when the frequency of the connecting bus is high enough. It is frequently employed at night. The volume of transferring passengers is typically not important in deciding where to institute dynamic control, since key motivating factors for using dynamic control are often elimination of the largest transfer waits, and public relations. From the point of view of improving the image of the transit system, the most important consideration is that people be aware of the possibility that the connecting buses will hold for them, rather than whether large numbers of people actually use it.

There are different approaches to the issue of providing user information about this transfer policy component. Some properties make an effort to inform passengers that dynamic control is used, but others only inform passengers when they complain about overly long transfer wait times at particular points. Large properties usually do not publicize the availability of dynamic control, for fear that the volume of requests would overwhelm the capacity of the radio system. In addition, there may be a desire to limit the number of disturbances of running times.

Larger properties which make marginal use of dynamic control generally tend to hold buses for one or two minutes. This is shorter than in the case of smaller cities because of the multiple transfer points and the greater difficulty encountered in making up lost time on large properties. Dynamic control of this type tends to be used in the evening, and for transfers to routes with long headways.

8.3 Current Practice -- Rail

Almost all rail properties use dynamic control at some bus/rail transfer points, and a few use it at rail/rail transfer points as well. The basic rationale behind dynamic control involving rail is the same as for dynamic control of bus/bus transfers, though communications equipment and procedures may vary. It should be noted that dynamic control in the bus/rail context is almost invariably applied to bus rather than rail vehicle movements, thus facilitating rail to bus transfers. This is due to the typically higher frequency of rapid rail which minimizes the benefits attainable from holding rail vehicles and the possibility of creating systemwide operational disruptions. There are isolated instances where rail vehicles are held. For instance, in Westport the commuter trains in the morning will occasionally hold for a very short time to permit a late bus to come in. However, this is an exception.

The informal holding of a bus for a train which is scheduled to arrive need not involve formal communication methods. All that is necessary is that the bus arrive at a train station where there are usually transferring passengers, and wait briefly (e.g., 1 or 2 minutes) for the train to arrive. This form of dynamic control is most often applied in the evening and toward the last train trips of the day, when bus frequencies are low.

The second type of dynamic control is a formal meeting based on train arrivals. In this case the bus is formally scheduled to meet a particular train and hold until passengers arrive from that train. Sometimes if there are later buses and the train is very late, a bus will only wait 5 to 7 minutes. Formal meeting does not require special communications equipment. However, it does require the commitment of a bus to

meet a particular train. It may also require that bus operators take measures to locate late trains. For instance, Westport attempts to contact the dispatcher in case of very late trains, and AC Transit (which runs buses under contract to meet BART trains in the evening) will have its bus drivers call the BART central control if the train is more than 15 minutes late. These methods of communication, though, are informal and do not form an important part of the formal meeting strategy.

The third type of bus/rail dynamic control, formal holding, attempts to mitigate the problems caused by the fact that there is often a large spatial separation between bus and rail (see Chapter 5). Moreover, if the rail route is underground, the bus driver may not know that a train has come in, and might otherwise pull out while the rail passengers are traversing the transfer distance. Therefore, it can be helpful for the bus driver to know when the train has or is about to come in, so that the bus can be held until the transferring passengers arrive.

The means by which this is accomplished in many cities (e.g., San Francisco, Cleveland, Philadelphia) is to have a light at street level which is illuminated when a train enters the station. The bus driver or starter knows how long it typically takes all transferring passengers to reach street level, and during off-peak hours will hold for that length of time (typically 4 to 5 minutes). The bus schedules usually include enough recovery and layover time to take into account the holding time at the rail station.

Formal holding can also be employed for transfers to rail. In Philadelphia, at the transfer point between the two subway lines, a light on one rail platform signals the arrival of a train on the other platform. In the evening or off-peak, this lets trains on the first line hold for 1 or 2 minutes if a train with transferring passengers arrives on the other line.

Another case, where formal holding of rail vehicles would have been helpful, occurred in Cleveland. At one rapid station people on a particular bus in the evening consistently missed the train as it pulled out of the station. This happened so persistently that the people called the dispatcher, who at one point stopped the train enroute and sent it back to the station. This led to significant disruptions in downstream schedule adherence, and illustrates the potential applicability of a formal holding strategy.

Figure 8-2 lists the different types of dynamic control and holding strategies, together with examples of properties which employ them.

8.4 Consequences

Bus Transfers

Costs

Because dynamic control involves real-time operator actions, there may be significant operational consequences. Surprisingly enough, users of dynamic control do not view it as disturbing the operation of the bus system very much. If a bus is held for a couple of minutes it is generally believed that the time can be made up. These operators therefore see dynamic control as an added service which does not require extra layover time to absorb the added uncertainty.

Several important qualifications must be made to this optimistic statement. On a bus system with no schedule layovers and otherwise highly reliable service, use of dynamic control on one run can adversely affect schedule adherence on subsequent runs if "speeding up" is not feasible. Large properties which use dynamic control can suffer from interference between multiple transfer points on the same line. If dynamic control is used extensively on a large property,

Figure 8-2

EXAMPLES OF RAIL PROPERTIES USING DYNAMIC CONTROL

<u>Informal Holding</u>

Washington
Boston

<u>Formal Meeting</u>

Westport
Detroit
San Francisco
Chicago

<u>Formal Holding</u>

Cleveland
Philadelphia
San Francisco

there may be further operational problems connected with excess radio traffic and the need to balance conflicting demands from passengers. In the words of one operator, "the passengers in the bus being held get upset and tell the driver they don't care about the other bus." The need to make this type of decision in real time is a distinct operational problem.

For most transfer components, the effects on operations translate immediately into costs. The major cost for dynamic control, however, is the initial purchase of the radios. Available radio systems span a wide range of possible costs and will have many nontransfer-related beneficial uses (e.g., reporting vehicle breakdowns or criminal incidents). The decision of whether or not to buy radios may therefore often be made on nontransfer-related grounds.

The other important cost consequence of dynamic control relates to the additional layovers which may be needed. However, layovers are generally not used to compensate for the variance induced by dynamic control. Operators only hold buses for relatively short times because if they had to build extensive layover times into the schedule, they might as well alter the entire schedule. The one exception to this costless approach occurs on pulse properties, where the incremental "guarantee" that vehicles will meet may have to be compensated for by additional layover time in order to avoid interference with subsequent pulses.

User Satisfaction

Dynamic control has several distinct effects on user satisfaction. When dynamic control is used as a stand-alone substitute for schedule coordination, the gain in user satisfaction for those people transferring to the controlled route is liable to be large, especially if it is late at night or the frequency of the controlled route is low. However, individuals boarding the controlled route after the control

point may experience extra delay (waiting time and uncertainty) if the bus does not catch up with its schedule quickly. The satisfaction of the riders already on the bus being held is not reduced significantly (because of the relatively low importance of in-vehicle time) unless the holdover is particularly long, or the riders are trying to make a connection at another transfer point, and the bus they are connecting with does not hold for them. This is why properties with multiple transfer points on the same routes find it difficult to use dynamic control to any great extent.

When dynamic control is being used in an area with serious schedule adherence problems, the effects on user satisfaction are different. The people transferring experience an even greater gain in user satisfaction since, with the uneven headways of the connecting route, their expected wait time is higher (see Chapter 10). On the other hand, dynamic control is not likely to detract from the level of satisfaction of the riders of the controlled bus or those "downstream," since they would experience schedule adherence problems in any case.

Dynamic control, used in conjunction with timed transfers, raises user satisfaction significantly. As outlined above, the "guarantee" that buses will meet to exchange passengers is a crucial element in cutting down the mean and variance of wait time associated with transfers, the central purpose of timed transfers. Once again, though, there are "downstream" users who may be adversely affected.

Ridership and Revenue

Generally, the ridership consequences of dynamic control as a separate option are not significant. No important increases in transferring ridership which can be attributed to this option have been observed by operators. Also, people who board downstream from the transfer point do not seem to be

particularly discouraged by the increased uncertainty in wait time, at least when the "hold" is short. Operators tend to view dynamic control as a public relations measure, so that induced ridership is indirect, and a secondary concern. However, when used with timed transfers, dynamic control definitely is a key contributor to increased ridership. Hence, revenue will increase significantly when dynamic control is combined with timed transfers but insignificantly when it is used independently.

Rail Transfers

Dynamic control applied to the bus side of rail/bus transfers tends not to have large operational consequences. The effects of holding a bus for a few minutes have already been outlined, and are generally minor. Unless buses must hold for unreliable trains and poor communications exist between bus and rail, dynamic control of buses for bus/rail transfers does not lead to significant operational problems. This contrasts with dynamic control of rail vehicles, which may produce such operational difficulties as vehicle bunching if frequencies are sufficiently high.

Once again, the costs of dynamic control arise from additional layover time and needed signalling equipment. Most properties do not build much additional layover time into the schedule for the purpose of dynamic control since (except in the case of formal meetings) the hold time is relatively short. Therefore the increase in operating cost is not great. The capital costs of train arrival signals, which are the predominant signalling devices now used for bus/rail transfers, are minor in comparison with other capital outlays. Maintenance costs are also very low.

Informal and formal holding increase user satisfaction by eliminating those occasions where transferring passengers just

miss their bus and have to wait the full bus headway. In Philadelphia, stations without formal holding produce a much higher rate of complaints to the operator about buses pulling away from terminals. Formal meeting will raise user satisfaction by guaranteeing a connection for the passenger travelling from rail to bus. For any type of dynamic control, holding buses for more than a small length of time (e.g., 5 minutes) may adversely affect the user satisfaction of riders boarding downstream. This may be insignificant for buses carrying evening commuter rail riders which only let out passengers or it may be quite important for buses which must make other connections.

Overall, operators tend to view dynamic control of rail transfers as a public relations measure (as in the case of bus/bus transfers), and find no significant direct ridership and revenue consequences accruing from its use.

8.5 Synthesis

Dynamic control, as a separate option, is appropriate when transfer flows are intermittent, when schedule coordination is difficult to provide, or when schedule unreliability is common. In the first case, dynamic control provides a way of making adjustments in operations only when they are needed to accommodate transferring passengers. In the second case, dynamic control can reduce wait time for passengers transferring between vehicles which are not scheduled by the same organization (e.g., rail to bus transfers). In both of these cases, dynamic control acts as a substitute for schedule coordination. In the third case, dynamic control can cause buses which would not have met otherwise to meet, thus mitigating the effects of schedule unreliability on transferring passengers.

The major constraints on the use of dynamic control tend to be the size and complexity of the system. Dynamic control, by definition, disrupts the normal operation of vehicles in the system. In a simple system this disturbance may not have widespread effects. On a more complex network of routes, though, use of extensive dynamic control may produce harmful schedule disruptions. There is also a limit on the number of dynamic control "messages" that a radio system can handle.

This does not mean that larger properties cannot use dynamic control. It does mean, however, that its applicability may be limited, and that there are inherent limits on the amount of ridership to be attracted by dynamic control alone. For example, if dynamic control regularly attracts ridership at a single transfer point, then an adjustment of the schedule, or schedule coordination, may be more appropriate than a regular real-time adjustment in operations.

There are many situations where dynamic control is a low-cost method for obtaining large gains in user satisfaction for some riders, and for improving overall public relations. Dynamic control is applicable where two low-frequency routes cross, and it is productive to guarantee that transferring passengers will make their bus. Dynamic control is also applicable in cases where a low-frequency route receives a significant volume of transferring passengers from a higher-frequency route, such as a trunk bus route or a rail line. By holding the vehicle on the low-frequency route to ensure that it meets an approaching vehicle on the other route, wait-time is reduced.

On timed transfer properties, a guarantee that buses will meet and be able to exchange passengers is necessary to attract new riders and ensure the satisfaction of old riders. Dynamic control with timed transfers requires some additional layover

time, although not as much as if layovers alone were used to overcome reliability problems. On both cost and user satisfaction grounds, dynamic control for bus/bus and bus/rail transfers is generally a workable compromise between no alleviation of schedule uncertainty (with people just missing buses), and the addition of enough costly layover time sufficient to absorb all headway variance.

Chapter 9
TIMED TRANSFERS

9.1 Introduction

A timed transfer is defined as any set of operator actions which provides some degree of certainty that vehicles on different routes will meet at regular intervals to exchange transferring passengers. Timed transfers can be thought of as the limiting case of both schedule coordination and dynamic control, since buses are scheduled and routed to ensure they meet in both time and space. However, since timed transfers have distinctly different consequences, they comprise a separate component of a transfer policy.

The simplest form of this option will be called "simple" timed transfers, where two routes are scheduled and operated to guarantee that some or all vehicles on the routes will meet at the transfer point to exchange passengers. At the other end of the complexity scale is the extensive use of timed transfers, to be known as pulse scheduling. The underlying principle of pulse scheduling is that vehicles on all (or most) routes which meet at the major transfer point are scheduled to arrive nearly simultaneously, hold until all the vehicles have come in, and

then leave together. When this occurs at regular intervals, the effect is as if the vehicles were pulsing.

In between these extremes are two other types of timed transfers. When pulse scheduling of buses is used only in the evening or off-peak hours, with low service frequencies and possibly long layovers at the transfer point, it is commonly called a "line-up." Compared to pulse scheduling, line-ups are found in larger cities. Another variant of timed transfers, "neighborhood" pulse, is found on large properties. It involves coordinating the schedules of neighborhood bus circulator routes to make travel within a section of a city easier.

Section 9.2 examines the types of situations where these variants of bus timed transfers are used, and the operator actions associated with implementing them. Section 9.3 briefly looks at timed transfers for rail. Such uses of timed transfers are quite uncommon, due to the large spatial separation between routes and the consequent long layover required. However, some examples of simple timed transfers between bus and rail are noted, along with cases where timed transfers for buses are combined with bus/rail schedule coordination.

Section 9.4 examines the consequences of timed transfers, and the last section, 9.5, suggests where timed transfers might be applicable.

9.2 Current Practice -- Bus

"Simple" timed transfers, where buses on two routes are guaranteed to meet regularly, illustrate the basic principles underlying timed transfers in general. Simple timed transfers are used on many properties, from the smallest to the largest. They are most commonly employed in the evening when both routes

have low frequencies. Simple timed transfers, almost by definition, are more likely to be found at outlying transfer points where few routes may meet. They are also common on long routes, which go to areas not served by other routes. However, their use is not restricted to any particular application setting. Figure 9-1 gives examples of properties which use each of the four types of timed transfers, including simple timed transfers.

In order to implement simple timed transfers, schedules must be adjusted so buses arrive at the transfer point at the same time. There are differences, though, in the way that operators handle the unavoidable problems of schedule unreliability. Some operators have the buses lay over for 2 to 5 minutes at the transfer point, assuming that such a layover provides enough of a cushion ordinarily to ensure that the buses will meet. Other operators utilize dynamic control to hold the first bus until the second bus arrives if the second bus has transferring passengers. "Static" control, where each bus is told to hold until the other arrives, has the problem that if one bus breaks down or is extremely late, the schedule of the second bus is needlessly disrupted. Therefore, true static control is rarely used, and a limit is typically placed on the length of time spent waiting. All of these operator actions, however, have the common objective of guaranteeing transfers with a low wait time between two routes.

Pulse scheduling, or extensive timed transfers, is the type of timed transfer which has the most far-reaching operational consequences. The properties which currently employ this option are extremely diverse. Figure 9-2 lists some of the important characteristics of the pulse properties participating in this study. Note that service area populations range from under 30,000 to over 300,000. A wide variety of communities are served all over the United States, including college towns, industrial cities, and bedroom

Figure 9-1

EXAMPLES OF PROPERTIES USING TIMED TRANSFERS BETWEEN BUSES

Type of Timed Transfer	Property
Simple timed transfer	Albany Washington, D.C.
Pulse scheduling	Fresno Lafayette Brockton Westport Lewiston Haverhill
Line-up	Knoxville Portland, OR Columbus Memphis Toledo Albany
Neighborhood pulse	Denver Portland, OR

Source: Operator interviews.

Figure 9-2

CHARACTERISTICS OF PULSE PROPERTIES

City	Population of Service Area (Thousands)	Transfer Charge (Cents)	Total Annual Ridership (Thousands)	Approximate Fleet Size	Approximate Number of Routes in System[1]	Pulse Frequency (Minutes)[2]	Number of Buses Meeting Each Pulse
Eugene	210	0	2860	67	20	30	12
Lafayette	110	5	1100	29	14	30	14
Brockton	100	0	2790	32	16	45[3]	15
Westport	30	0	640	25	7	35	7
Fresno	310	0	4400	99	21	30	12[4]
Lewiston	70	0	460	18	9	30	9
Everett	50	0	1020	18	12	30	11
Haverhill	50	0	90	3	6	30[5]	3

[1]Not including express routes.

[2]Generally constant throughout the day (see text).

[3]Some routes meet every 22.5 minutes at an intermediate pulse.

[4]With "syncopated pulse" (see text), the buses are divided seven and five between two adjacent pulse points.

[5]Because three buses run six routes, each route has a 60-minute headway.

Source: Operator interviews; timetables and maps from each property; APTA Operating Report, 1975; APTA Membership Directory - 1978.

suburbs. Annual ridership among the pulse properties ranges from the tens of thousands to over four million. Fleet sizes range from 3 buses up to about 100 buses. It is interesting to note, though, that virtually all of the pulse properties offer free transfers. This may reflect both a "philosophy" on pulse properties of simplifying and reducing the burden of transfers, and an effective marketing approach.

Several properties have employed some form of pulse scheduling for a fairly long time, showing that the pulse is not a recent innovation. At least one property (Eugene, Oregon) has had pulse since 1910, when trolleys met intercity trains. Pulse scheduling on several other properties predates public control.

There are many reasons for implementing and maintaining a pulse schedule. Goals of increasing efficiency, making transfers easier, making the transit system easier to understand, attracting riders, and increasing coverage are commonly cited by operators. The ways that operators have used pulse to try to achieve each of these goals are examined below.

Important aspects of pulse transfers include service frequency, routing, schedule adherence, space for buses to meet and operator-information policies. Since all buses are meeting, it is possible to speak of a "pulse frequency" of which all route frequencies are a multiple. The most common pulse frequency is 30 minutes. Other pulse frequencies such as 35 minutes, and 45 minutes (with some buses meeting in between the major pulses), are also in use as shown in Figure 9-2. Virtually all of the properties using a pulse other than 30 minutes originally implemented pulse at a 30-minute frequency and later modified it because of schedule unreliability, increases in ridership which led to slower running times, or other site-specific reasons.

An interesting feature of the frequencies cited above is that they typically do not change much between the peak- and off-peak periods. Most pulse properties maintain the same frequency throughout the day, though some halve the frequency in the evenings and on weekends. Only minor insertions of extra buses are usually made during the peak hours.

Nonusers of pulse scheduling perceive significant obstacles to converting a large system which has a great variety of headways and running times to a single standard. An important decision in implementation, therefore, involves reducing frequency on some lines, which would reduce LOS, or increasing frequency on others, which is costly. Both possibilities require making "artificial" changes to the schedule which may be wholly unsatisfactory in some settings. In large cities, especially, forcing a wide variety of routes to meet in time and space may be essentially unfeasible. In the opinion of one experienced transit professional, "in large cities, crosstowns are better and cheaper, too."

Given the ranges of headways which are found on different properties and the different ways of making them compatible, it is somewhat surprising to find that 30 minutes is almost uniformly perceived as the preferred pulse frequency. Many operators believe that a 30-minute headway makes the transit system easier to understand. Also, half-hour headways are quite compatible with clock-face scheduling. These reasons are consistent with the design of timed transfers as a popularly supported, easily understood, and not easily disrupted public transit system.

It should be noted that on systems with lower than 30 minute headways, people may experience short transfer times without timed transfers. This implies that pulse properties are naturally made up of those which have low service frequencies because properties on which a high frequency was

appropriate might not find that pulse was worth the effort to implement.

The need for all or most routes to have the same headway is an integral part of a pulse system, constraining in turn the routing of buses. When implementing pulse, many properties find that their natural routes are too long and that pulse limits their route-miles. A typical remedy is to cut short the ends of the routes. Also, as outlined in Chapter 6, through-routing can be used to achieve headways which do not divide evenly into route run times. On the other hand, several properties have routes which are too short. The operator response to this problem is typically to either increase layovers to equalize running time, or extend the bus route by loops or other means, thus adding area coverage.

In practice, the choice of a pulse frequency can never be made independently of routing decisions. A major influence in the balance between frequency and routing is the size and shape of the relevant transit district. Lafayette, Indiana and Brockton, Massachusetts, are two pulse cities which have relatively compact service areas, and thus have no trouble operating a 30-minute pulse with good loop area coverage. Another pulse property, Everett, Washington, had difficulty expanding the length of its routes because the service area is long and thin, and the CBD is not in its geographic center. In general, properties whose CBDs are in the geographic center of the relevant area find it easier to pick an appropriate pulse frequency and then equalize running times on different routes based on the size of the area.

Schedule adherence is a major problem for pulse properties. The reasons for schedule unreliability tend to be the same as those on nonpulse properties: traffic congestion, breakdowns of new buses, and interference from trains. (Chapter 10, Schedule Adherence, covers this question

in detail.) However, since the essence of timed transfers is to ensure that transferring passengers make connections, maintaining schedule adherence is more important on pulse properties.

Two strategies are available for coping with schedule unreliability problems on a pulse system. The first strategy is to build extra layover time into the schedule. Most pulse systems use layovers of 5 minutes or less out of each half hour. Use of additional layover time is limited if the same schedule is to be used for both peak and off-peak. That is, if long enough layovers are added to absorb peak-hour unreliability, there will be costly unused layovers during the off-peak period. However, layovers of 5 minutes or less are usually not sufficient to handle all schedule adherence problems.

Therefore, almost all pulse properties also use the second possible strategy, dynamic control, to mitigate schedule reliability problems at the pulse point. In general, buses will hold for a maximum of 3 to 6 extra minutes for late buses before leaving the pulse point. As described in Chapter 8, the driver of the late bus, if it is radio equipped, can inform the dispatcher or starter which routes will be receiving transferring passengers, enabling a selective release of buses.

Typically, "lengthy" detention of buses through dynamic control is employed most effectively during off-peak hours, the last pulse of the day, and towards the end of peak. Its use is avoided at the beginning of peak hours because during the peak buses will have difficulty catching up to the schedule if they have been held any length of time. It is generally thought to be better to let one or two peak-hour buses miss the pulse than disturb the rest of the system. On the other hand, it is very important on the last trips of the day to ensure that no one is stranded.

Some properties use short layovers and "static" control (holding "blindly" up to 5 minutes) to deal with schedule uncertainty. These operators, who do not have radios, sometimes encounter a situation which might be called "disintegrating pulse." Because layovers are short, and buses may be detained inefficiently, routes on which traffic congestion is bad may not be able to stay on schedule, and are simply dropped from the pulse.

Several nonusers of pulse scheduling believe that schedule adherence problems sometimes cannot be overcome by any strategy. Indeed, trip time variance at peak hours can be greater than the headway in some larger systems. Such schedule unreliability is clearly incompatible with a pulse system which does not have enormously large and costly layovers built into the schedule. Furthermore, such schedule adherence problems may be inherent in operations in congested areas having heavily utilized short headway bus operations. This is clearly a limiting factor in the use of timed transfers.

Another important requirement of pulse scheduling is the provision of space for buses to meet at the pulse point. Most pulse properties have a single pulse point which is located in the CBD. Typically 9 to 12 buses occupy the pulse point at each pulse, although as many as 15 buses or as few as 3 have been observed in practice, depending on the size of the system. These numbers refer only to the buses meeting the pulse; pulse points may have unsynchronized routes terminating there as well.

Finding space for all buses to meet, a common problem for the pulse properties, is seen as an even bigger problem by nonusers of pulse. There is a need to keep all pulsing buses close together for the benefit of riders and for better control

of the pulse. Typically, buses are distributed over one or two blocks along a street. This distance may create problems for some passengers, since it is far enough to cause passengers to miss their buses. In general, though, the use of on-street stops is not viewed as intolerable by operators. Of the pulse properties participating in this study, only Brockton has an off-street facility, and that was only opened in March 1979.

Two other properties have adopted atypical solutions to the problem of arranging buses at the pulse point. Because of space limitations, Fresno, California, has had to adopt what might be called "syncopated pulse." A syncopated pulse system has two pulse points, fairly close together, with the buses at one pulse point routed so that they pass by the other pulse point both coming in and going out. If both are scheduled to pulse at the same time, the buses which terminate at the first pulse point drop off passengers at the second pulse point just before it pulses, and pick up passengers at the second pulse point just after it pulses. In this way, passengers can make their transfers within a reasonably short length of time without all the routes having to terminate at the same spot.

The second property which has used an unusual pulse point arrangement is Lafayette, Indiana. Until January 1979, Lafayette had two pulse points, one in the CBD and a second at Purdue University. The two pulse points were approximately one mile apart across a river, and connected by a shuttle route which met both pulses. This arrangement was originally instituted to increase coverage to the west side of town and to keep large numbers of buses off the single major bridge over the river. However, Lafayette moved back to a single pulse point in the CBD in January 1979 because of problems in adhering to schedules.

This experience raises the problem of interference between pulsing buses, both parked and moving in platoons, and auto

traffic. In many cases, some traffic engineering work and cooperation from the police are necessary to ensure smooth operations. These aids, and the possible tendency of autos to avoid "pulse" streets, tend to keep traffic congestion problems to a minimum.

The final component of current practice among pulse properties is the degree to which they publicize their use of pulse scheduling. Several properties make it clear from their schedules that pulse scheduling is a keystone of their system. Other properties place some emphasis on pulse scheduling without making it the dominant feature of the system. Finally, there are some properties which do not highlight their use of pulse scheduling at all. This last group includes systems which have historically had some sort of timed transfers or clockface scheduling, and do not regard it as an especially distinctive feature.

The other variants of timed transfer, line-ups and neighborhood pulse, are basically pulse scheduling applied in different situations. A line-up is pulse scheduling used in the evenings and off-peak hours. A neighborhood pulse is pulse scheduling used on only a portion of the system. Most of the operator actions associated with these variants are similar to those for pulse scheduling. The major differences that do exist are pointed out below.

Line-ups are used by many nonpulse properties in the evening or on weekends. The populations served by properties participating in this study and using line-ups range from 190,000 up to 1,800,000, with all but one over 500,000. Most of these properties use a headway of one hour for their line-ups, which is the same headway often used by pulse properties in the evening as well.

Given that the term "line-up" conjures up an image of a row of buses sitting in a line for long stretches of time, it

is important to note that most line-ups have no more than 5 to 10 minute layovers. Again, there may be some adjustments made in routing to accommodate the schedule. For instance, one property reduces some coverage of outlying suburbs, while another adds a "Night Loop" to some routes. Most of the other actions taken by properties are the same for line-ups as for pulse scheduling. In addition, emphasis may be placed on the fact that line-ups tend to guarantee that no one gets stranded after the last trip of the day.

The difference between neighborhood pulse and full-scale pulse systems is the size of the system in which the pulsing routes are found. With neighborhood pulse, a set of local routes pulse together to facilitate travel within a neighborhood. Because this may occur in areas outside of the congested CBD, neighborhood pulse can be found in very large cities. For instance, both Portland, Oregon, and Denver are planning to implement neighborhood pulse at several points. This is part of a conversion of their route structures to a bus transit center concept, with grid instead of radial routes. However, neighborhood pulse may be implemented on any property having non-CBD subcenters which are logical transfer points. The actions required to do this are quite similar to the actions associated with pulse scheduling.

9.3 Current Practice -- Rail

Timed transfers between rail and bus, or between rail and rail, are very uncommon. There are several reasons why the timed transfer concept, which is so productive in many bus/bus transfer settings, is not more widely used in rail. First, rail operators are reluctant or unable to adjust rail schedules and ensure that they will be adhered to in the way that timed transfers would require. Second, the high frequency of most

rapid rail lines means that most scheduling options designed to benefit bus to rail or rail to rail transferees are unprofitable, since the expected transfer time to rail is low already. Third, and most important, the larger spatial separation for transferring passengers inherent in rail requires longer layovers at the transfer point, which are costly, disruptive to downstream passengers and upstream operations, inconvenient to through-riding passengers, and generally difficult to control. For example, timed transfers were considered between the two subway lines in Philadelphia in the evening. They are both on 20 minute headways, so headway adjustments would have been no problem. In order to guarantee the timed transfer, however, one train would have often been required to hold for five minutes or more. It was decided that this would cause too much disruption and inconvenience for through-riders on the train being held.

However, there are some examples of timed transfers for bus/rail transfers which have been implemented or considered. For instance, in Westport, where bus schedules are coordinated to feed the commuter rail, the buses have recently begun to receive a reverse commuter flow in the morning of people getting off the train and taking the bus to work in Westport. Since the bus and train are exchanging passengers, this is the equivalent of a timed transfer. However, this timed transfer does not currently work very well because the older bus schedule does not allow sufficient time to let these new passengers off at their stops. That is, buses often have trouble making the next train connection.` This may necessitate schedule changes in the future.

Another case of bus/rail timed transfer can be found in New York. The Metropolitan Transit Authority runs a service from midtown Manhattan to Kennedy Airport which consists of a special rapid transit train on 20 minute headways. This train is met at a train station near the airport by a bus, which then

takes the passengers to the airport itself. In practice, people can transfer from the rail to bus easily, but the bus does not always arrive in time for people to transfer from bus to rail. Compounding this problem is the fact that the train cannot hold for the bus (see Chapter 8) because of scheduling constraints. Remedial action will be necessary to adjust the bus route and/or schedule to ensure better connections.

There are also at least two cases where rail is involved in a bus pulse or line-up. On the Norristown division in Philadelphia, four bus routes pulse hourly (arriving at five minutes before the hour, and leaving three minutes after) and are met by an interurban train which lays over at the pulse point for nine minutes. In Cleveland, the same light which signals buses that a train is in (see Chapter 8) also controls a line-up in the evening. When the light goes out, all the buses leave together. In both cases, the trains may not be formally actually "pulsing" with the buses, but there is at least some schedule coordination with layovers between the bus pulse and rail which often allows passengers to transfer in both directions.

A similar effect may be found for all instances of bus/rail schedule coordination cited in Chapter 7. Scheduling to facilitate rail to bus transfers may also aid bus to rail transfers if the bus is scheduled to arrive early enough. This would permit bus passengers to reach the rail platform and effectively allow the bus and train to exchange passengers. However, since there is no provision to hold the train if the bus is late, such forms of schedule coordination cannot really be considered timed transfers.

9.4 Consequences

This section focuses almost exclusively on the consequences of bus/bus timed transfers. The consequences of bus/rail and rail/rail timed transfers, which are much less prevalent, are treated briefly in a separate subsection.

Bus Transfers

The use of timed transfers does not inevitably lead to any particular set of consequences. Simple timed transfers, pulse scheduling, line-ups, and neighborhood pulse clearly all require different levels of effort and generate impacts of different magnitudes. Even within properties using pulse scheduling, impacts vary greatly depending on the required operator actions. This wide divergence of possible impacts follows directly from the multiplicity of actions making up timed transfers described above. For the purpose of detailing consequences, these operator actions will be divided into the five categories in the previous section: schedule changes, routing changes, schedule unreliability control, provision of space, and provision of user information. The analysis of each type of consequence -- cost, user satisfaction, ridership, and revenue -- will focus on those categories of operator actions which have the greatest impact.

Costs

The first type of consequence to be considered is cost. The changes in bus-hours and bus-miles which come from altering headways to match different routes have the greatest potential influence on cost. In practice it is not clear whether this is an important effect. Frequency changes for simple timed transfers and line-ups seem to be small, especially since

headways in the evening are often fixed by policy. Frequency changes for pulse scheduling and neighborhood pulse are potentially significant, but it is impossible to tell in general whether frequencies will be raised, lowered, or both on any particular property. In practice, pulse properties appear to have somewhat longer peak headways than comparable nonpulse properties, and somewhat shorter base headways. The operator may feel that because of reduced transfer time, he can raise the headways during the peak and still provide a comparable overall level of service. Alternatively, he may decide to maintain the peak headway to accommodate work riders, and raise the base frequency accordingly. In general, the pulse properties participating in this study do not attribute major cost consequences to frequency changes mandated by the use of timed transfers. Because of site-specific factors, though, it is not possible to anticipate the direction or magnitude of the changes in service frequency needed to implement pulse in current nonpulse cities. These impacts must be assessed on the basis of the policies selected by the operators and the preexisting schedule.

The systematic dollar cost differences that exist between pulse and nonpulse properties stem mainly from extra layover time built into the schedule to ensure schedule reliability. Because timed transfers are based on guaranteeing that buses will meet, more system resources are devoted to this end. As extra layovers are built into the system, two distinct effects can occur. With a greater fraction of vehicle time spent idle, costs as estimated on a <u>per mile</u> basis will <u>increase</u> due to the decrease in VMT. Actual <u>total</u> operating costs may <u>decrease</u> due to savings in bus running costs (if no more buses are added). The conflict between these indicators and the small expected size of the impact are compatible with the indecision of many operators concerning the overall cost impacts of pulse scheduling.

A cost of pulse scheduling which can be significant is the cost for the street space used by the pulsing buses. This cost is not normally a direct financial burden on the operator in the usual sense. However, street space consumption by the buses can cause an increase in traffic congestion and a reduction in parking meter revenues as well as aesthetic problems. These costs are not borne by the transit operator, but may have to be taken into account when deciding whether or not to implement pulse scheduling.

User Satisfaction

User satisfaction for transferring passengers increases significantly almost any time any type of timed transfer is used. However, there are factors which appear to influence the degree of change in user satisfaction. These factors are service reliability, comprehensibility, frequency and, to a lesser degree, coverage.

Reliability is the key element in determining whether user satisfaction increases sharply with timed transfers. If riders are ensured of a very high probability of making their connection, both the average transfer wait time and variance of transfer wait time will go down. The variance is especially important because one bad experience can counteract the effects of a large number of good ones. Missing connections on simple timed transfers and line-ups, with their long headways, leads to particularly long transfer wait times. Therefore, operator actions to ensure a high degree of reliability of making connections are essential for a large gain in user satisfaction.

Comprehensibility of the system is a second important factor in user satisfaction. If an operator makes riders aware of the timed transfers, then the system is easier to understand and use. Riders who want to transfer need not worry when the

connecting bus will arrive at the transfer point. Schedules are simplified and made less confusing. This gain in comprehensibility applies to simple timed transfers, line-ups, and neighborhood pulse as well.

Frequency also affects user satisfaction with timed transfers; however, its effect is essentially inverse. High frequencies lead to low average transfer wait times, even without timed transfers, so the implementation of timed transfers would have a reduced positive effect on user satisfaction. On the other hand, low frequencies mean that timed transfers can have a large positive impact on average transfer wait time, and hence on user satisfaction. Simple timed transfers and line-ups, which are typically utilized at times of low bus frequency, are thus more likely to increase user satisfaction greatly. It should be emphasized that this relationship with frequency focuses on the change in user satisfaction induced by timed transfers. The overall level of user satisfaction would typically be higher with high frequencies.

The final factor, coverage, is less significant than the first three in determining user satisfaction. From the description of possible operator actions in Section 9.2, it is clear that operators often adjust routings to accommodate pulse scheduling or line-ups. For each route these changes can affect the overall coverage on the outlying portions of the routes, the streets used to reach the downtown terminal point in the allocated running time, or the location of the terminal point itself. In practice, pulse scheduling and line-ups have had little effect on coverage of outlying areas. However, in at least two cases adjustments to the terminal location of the pulse point affected the level of service available to both transferring and nontransferring passengers. In Brockton, the off-street transfer facility was located several blocks away

from the previously used pulse point, which had been closer to the center of town. This led to a net increase in the distances that many people had to walk to access transit. In Lafayette, when the dual pulse point system was instituted, people who had formerly traveled on one bus from the west side of town to the CBD were compelled to transfer, thus reducing their level of service. In general, though, coverage in the context of timed transfers seems to have been affected in only a minor way.

It is important to consider how changes in user satisfaction affect different groups. Geographically, the four categories of timed transfers inherently have different consequences for different groups of riders. Simple timed transfers only increase user satisfaction for the individuals transferring between two particular routes. Likewise, the effects of neighborhood pulse are restricted to riders in a particular area. Line-ups, typically systemwide, only have consequences for people traveling during off-peak hours. Finally, pulse scheduling will affect the user satisfaction of almost all riders.

For pulse scheduling, both market surveys and operator opinions indicate that elderly, young, and frequent transferees experience the highest gain in user satisfaction from pulse scheduling. In particular, pulse scheduling makes transferring much less onerous for the elderly. On the other hand, riders making peak-hour work trips seem to have much less of a gain from pulse scheduling due to the heavily radial nature of their trips.

Ridership

Simple timed transfers or line-ups clearly do not produce large ridership gains, since the typically long headways on the originating leg remain an important determinant of ridership.

On the other hand, some properties have experienced substantial increases in ridership due to the use of pulse scheduling. However, it should be noted that many of these properties instituted other service improvements simultaneously with the pulse scheduling.

In Brockton, for example, ridership increased six-fold at a time when VMT was increased four- to five-fold. Since only 25 percent of passengers now transfer, and the reliability of service has drastically improved, a reasonable estimate of the increase in ridership directly attributable to pulse scheduling may be on the order of 10 percent of current ridership.

This estimate is substantiated by the experience of Superior, Wisconsin, where ridership rose 10 to 12 percent with the advent of pulse scheduling and no other important changes in service. However, several pulse operators (including those in Everett and Lewiston) see no definite link between pulse scheduling and ridership.

In addition to shorter wait times at transfer points, there are other features of a pulse schedule system which induce ridership. First, reliability is very important in attracting ridership. Providing user information which increases the comprehensibility of the system for infrequent riders and nonriders also seems to be a key factor in attracting ridership. However, the origin-destination patterns of the property are probably more important than either of these in determining the ridership consequences of pulse scheduling. For example, trip attractors outside the CBD must exist for pulse scheduling to increase the amount of transferring.

As in previous chapters, it is possible to construct examples of how ridership changes due, in this case, to implementing pulse scheduling. The characteristics of pulse properties are well-specified, and the option affects all

transferees equally. Consider a small property, where all routes meet at one point, all have headways of 30 minutes, and the overall transfer rate is 20 percent. Before pulse scheduling, the average out-of-vehicle time for transferring passengers will be 30 minutes (15 minutes transfer time, plus 15 minutes initial walk and wait time and final walk time). With pulse scheduling, transfer time will drop to 5 minutes, for a total average out-of-vehicle time of 20 minutes.

Under this scenario, the increase in ridership due to pulse scheduling can be calculated in two different ways. The first way utilizes the -.7 elasticity of demand with respect to out-of-vehicle time.[1] Since with pulse scheduling out-of-vehicle time for transferees drops by 33 percent, the number of transferring passengers will rise by 23 percent (.33 x .7). If the initial transfer rate was 20 percent, the overall ridership will rise by 4.6 percent (.23 x .20). The new transfer rate, 24 percent, is consistent with the results presented in Figure 4-1, which showed that the average transfer rate of pulse properties was approximately 27 percent. That is, we may expect properties to adopt timed transfer if they already have higher than average (20 percent) numbers of passengers transferring, or if they have non-CBD transit type destinations which would be well served by timed transfer. Also, the 4.6 percent increase in ridership with timed transfer in the above example does not take into account the change in overall user perception of the system as conducive to reliable transferring. There appears to be a belief shared by several pulse operators that timed transfers at the downtown terminal promote a comprehensible, easily "imaged" and popularly supported system that leads to more riding than simple reductions in waiting time between two connecting lines would suggest.

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[1] Domencich, Kraft, and Valette, op. cit.

A second elasticity-based method for predicting the ridership consequences of pulse scheduling uses the pre-BART aggregate demand elasticity for San Francisco ridership with respect to transfer time (only) calculated by McFadden (1974) of -.26. For the above example, this yields an overall ridership increase of approximately 17 percent (.67 reduction in transfer time x .-26). It should be noted that this increase may be equated in the above example to an elasticity of -2.5 for all out-of-vehicle time alone [17/20 percent x .33]. There is support for bus service elasticities this high under conditions of infrequent service (e.g., comparable to long waits at transfer points -- pre-pulse) and relatively high fares.[1]

In any event, 5 to 17 percent appears to be a reasonable range for the ridership effects of pulse scheduling. The higher increases would be more likely for systems which increased service reliability at the same time and/or which had the potential for significant riding to nondowntown terminal locations because of the presence of major attractors for discretionary trips or trips by the elderly to dispersed destinations.

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[1]Carstens and Csanyi derived estimates of price and service elasticities under various price and service levels for 13 urban bus systems in Iowa using annual data from 1955 to 1965. R. L. Carstens and L. H. Csanyi, "A Model for Estimating Transit Usage in Cities in Iowa," HRB Record 213, 1968. Their results are further analyzed in Public Transportation Fare Policy, prepared for U.S. DOT by Peat, Marwick, Mitchell and Co., May 1977, pp. III.40 to III.44.

Revenue

The revenue consequences of timed transfers follow directly from ridership consequences, as long as the distinctions between groups paying different fares are observed. The key question is whether the revenue gained from increased ridership covers the cost of setting up a reliable pulse schedule system. This question can be addressed in a purely hypothetical case using the above example. Consider again the small property with 30-minute headways and without pulse scheduling. To implement pulse scheduling and attract ridership, reliability must be increased by adding layover time. Assume this added layover time to be 5 minutes added to the 55 minutes previous running plus layover time (two buses on each route).

In this example, assume pulse scheduling is to be implemented at no additional operating cost. Therefore, VMT must be decreased proportionally -- that is, by 9 (or 5/55) percent. (In fact, the decrease may be slightly less because layovers decrease mileage-related costs.) Using the typical bus VMT service demand elasticity of -0.7 yields a VMT-related decrease in ridership of 6.3 percent. This ridership decrease would probably be less because the VMT change took place at the ends of the routes in low-density areas. Whether 5.0 percent or 6.3 percent, this decrease in ridership from the added layover time is at the low end of the range of the above estimated pulse schedule-induced ridership increase. Hence, a no-cost implementation of pulse scheduling under this scenario may still attract additional ridership, and be a productive option in this situation.

It is very important to note that the actual cost and ridership effects of timed transfers in any real application depend heavily on policies undertaken by the operator to equalize headways, provide adequate space for all buses to meet, etc. The site-specific nature of all of these factors makes it impossible to generalize results except to say that

many operators believe that timed transfers of some sort are the most efficient means available to provide improved levels of service under many circumstances.

Rail Transfers

Due to the limited number of applications of bus/rail or rail/rail timed transfers, this subsection will use the information presented in Section 9.3 to estimate the consequences of simple timed transfers between rail and bus or rail. Such a timed transfer would be much more costly and disruptive than a bus/bus timed transfer because it would require longer layovers to guarantee a reliable connection. That is, the spatial separation for bus/rail and rail/rail transfers is typically longer than for bus/bus transfers, (except in selected cases of commuter rail and across-the-platform transfers), necessitating more time for the vehicles to exchange passengers.

The increase in user satisfaction with bus/rail or rail/rail timed transfers will not be as great as with bus/bus timed transfers, due to the typically higher frequency of rapid rail lines. Almost all bus pulses are on a half-hour headway, while rail headways are usually shorter. Hence, passengers utilizing a timed transfer to transfer to rail will benefit less than passengers utilizing a timed transfer (bus/bus or bus/rail) to transfer to a bus.

How ridership would increase with bus/rail or rail/rail timed transfers cannot be stated in general terms. As noted earlier, the reliability of the connection is an important part of attracting ridership. It is not clear that high reliability can in general be achieved for bus/rail or rail/rail timed transfers, given the difficulty of coordinating two spatially separated vehicles, possibly under the control of two different operating authorities. Even between buses, simple timed

transfers do not have a significant ridership effect. Therefore, it can be concluded that the ridership and revenue consequences of bus/rail or rail/rail timed transfers are positive, but in most situations will not be large.

9.5 Synthesis

This section outlines possible criteria for determining where timed transfers are applicable. Almost all the material refers to bus/bus timed transfers, although there is a limited discussion of the appropriate settings for bus/rail and rail/rail timed transfers. It should be emphasized that due to the importance of site-specific factors, this section can only provide general guidelines, rather than strict rules.

Property size is the principal criterion for bus/bus timed transfer applicability. Properties with less than 400,000 people in the service area are generally able to use pulse scheduling at their main transfer point. On the other hand, larger properties often have line-ups, but do not have pulse scheduling. Simple timed transfers generally can be used on any system, though they are more likely to be found on medium-size properties. This is because small properties do not usually have significant outlying transfer points, and large properties have more complex systems for which the scheduling of several simple timed transfers may not seem worth the effort. Finally, neighborhood pulse is applicable to any system with subcenters which serve as logical pulse points.

Several factors affect the applicability of timed transfers. The first is schedule reliability, which is very important for increasing user satisfaction. A "disintegrating pulse" where people cannot be assured of meeting their bus eliminates the rationale behind the pulse system. Hence, cities which have problems with adhering to schedules would

have difficulty using timed transfers in general, and pulse scheduling in particular. Also, on large properties with severe schedule adherence problems, increasing user satisfaction via timed transfers would tend to be prohibitively expensive. This is one reason why large properties tend not to use pulse scheduling during the day, and instead concentrate on times when schedules are more reliable.

Service frequency also influences the applicability of timed transfers. At high enough frequencies (e.g., 15 minutes) the drop in average transfer time attributable to timed transfers is not significant enough to substantially increase user satisfaction and begin to offset the added costs of timed transfers in the centers of congested cities (e.g., street space, congestion, etc.). Since larger properties tend to have high service frequencies even during the day, this constrains the applicability of pulse scheduling and possibly neighborhood pulse as well. With low frequencies in the evening, line-ups can be used anywhere. On the other hand, low frequencies limit the amount of ridership which timed transfers can attract.

The same reasoning underlying the effects of these factors on the applicability of timed transfers for buses can be applied to bus/rail and rail/rail timed transfers. These options can therefore only be used in the evening or on commuter rail, when rail frequencies are low, and the reliability of transfers must be guaranteed without excessively costly layovers. Transfer reliability is enhanced if there are across-the-platform transfers, or buses which are dedicated to meeting the train.

For bus/bus timed transfers, space limitations on the number of buses which can meet have an important influence on its applicability. Twelve buses at a time is average for pulse scheduling, with neighborhood pulse having somewhat fewer and line-ups somewhat more. Large properties often have more than 12 buses arriving during peak and base periods. The difficulty

of finding a place in a congested area where all the buses can meet also explains why large properties avoid daytime pulses, resorting instead in some cases to line-ups in the evening when there is a less-congested CBD. Moreover, even if there is a place to meet, the distance between buses will exert a very significant effect on the transfer time.

Given these size-related reasons why pulse is implemented only in small properties and line-ups are implemented only in large properties, it is appropriate to outline reasons why utilization of pulse varies among small cities. Widely dispersed origins and significant numbers of non-CBD destinations indicate candidates for pulse scheduling. Geographic layout -- having the CBD in the center of the service area, for instance -- can make scheduling easier. However, the most influential factor seems to be a political climate in which transit innovation can occur. If political factors determine the level of service allocated to different areas, pulse scheduling may not be politically feasible. This type of constraint must be addressed on a case-by-case basis.

However, if the political climate is conducive to a major change and revamping of service, pulse scheduling is a politically attractive alternative. It also has the potential of being a cost-effective way of increasing service and ridership without necessarily increasing operating costs.

Chapter 10
SCHEDULE ADHERENCE

10.1 Introduction

Schedule adherence is an important aspect of the overall level of service supplied by transit properties and affects all riders on the system. However, the impact of schedule adherence on transferring passengers can be isolated and studied without losing sight of the much larger overall effects. This chapter focuses only on transfer-related issues connected with schedule adherence.

Section 10.2 reviews briefly the major causes of bus schedule adherence problems found in different cities. Section 10.3 compares the schedule adherence of rail to the schedule adherence of buses on the rail properties participating in the study. Section 10.4 explores the consequences of schedule unreliability for transferring passengers, while Section 10.5 concentrates on the interactions between service reliability and other transfer policy components. Schedule unreliability is found to be a major constraint on the components that can be utilized in a system's overall transfer policy.

10.2 Current Practice -- Bus

Nearly every property has some problems with bus schedule adherence, though these problems vary widely in magnitude between sites. During peak hours some properties experience headway variance greater than the headway itself, while other properties are on schedule 98 percent of the time. The causes of schedule unreliability also differ markedly among properties.

The most common cause of schedule adherence problems is, of course, traffic congestion. This happens mainly during afternoon peak hours, starting as early as 3:00 p.m., and to a lesser extent during morning peak hours. Delays incurred when picking up passengers constitute another important cause of schedule unreliability. Because passengers have to enter a bus through a narrow space, and usually pay as they enter, variation in demand which affects dwell time can disrupt the schedule.

Two rather unusual reasons for schedule unreliability are also cited frequently by transit operators. In many cities, buses experience substantial interference from freight trains at grade crossings. These trains sometimes engage in switching operations across the bus routes, leading to chronic lengthy delays. Several operators also find that breakdowns of new buses account for a large proportion of schedule unreliability. These problems have a substantial effect on at least some properties.

When a bus falls behind schedule for any reason, there is a tendency for its schedule adherence to continue to deteriorate because of "bunching". This occurs because of changes in the numbers of passengers boarding the bus as a result of the effective change in headways between buses. When a bus experiences an unscheduled delay, passengers continue to

arrive at "downstream" stops, further increasing the run time as described above. As the bus takes more time to traverse the route, the effective headway between it and the following bus decreases. Since the following bus encounters fewer waiting passengers, it traverses the route more quickly. In the limit, in the absence of remedial actions the buses meet or "bunch," increasing the variance in wait time experienced by passengers along the route.

It is beyond the scope of this study to analyze and evaluate the many remedial actions for schedule unreliability which have been suggested.[1] Traffic engineering measures such as preferential signals and reserved lanes can be used to reduce or avoid traffic congestion. Time points, using radio-based or automatic vehicle monitoring, can be used with appropriate holding strategies to keep buses from running ahead of schedule and control bunching. New York City, for instance, is planning to install an automatic vehicle monitoring system for this purpose in part of its bus system. Skip-stopping with passing can also be an effective strategy for dealing with bunching. Finally, properties experiencing bus breakdowns or excessive delays can have spare buses on hand to insert on a route. Clearly, there are a variety of strategies which could be undertaken, each of which entails operator effort and has costs and benefits to transferring and nontransferring passengers alike.

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[1]For example, see TSC Staff Study, Transit Service Reliability, by Mark Abkowitz, Howard Slavin, Robert Waksman, Larry Englisher and Nigel Wilson, March 1978, Section 6.

10.3 Current Practice -- Rail

Rail properties also have significant problems with schedule adherence. In many ways, though, rail schedule adherence is less important than bus schedule adherence for transferring passengers. Rail rapid transit typically runs on very short headways during peak hours, so that waiting time between trains is short. In fact, many properties do not give out exact schedule information for rail transit during the peak hours, indicating only that trains arrive "every 5 minutes or less."

Also, transferring passengers at rail stations may have more opportunities to engage in productive activities (e.g., shopping), and experience a higher level of comfort due to rail station facilities than their bus counterparts.

Rail service itself tends to be more reliable than bus due to its use of an exclusive right-of-way. While variations in demand may still cause changes in dwell time, the fact that traffic congestion and signals generally have no effect on rail operations tends to produce more reliable service. The exceptions to this are caused for the most part by hardware reliability problems and the inherent limitations of fixed guideways. If a train breaks down or is excessively delayed, it is often not possible to keep it from blocking other trains on the route for a considerable period of time. Since equipment failure can occur on all types of properties, a given rail operation may not be more reliable than bus service. Indeed, many commuter rail operations which utilize deteriorating rolling stock and track which requires frequent maintenance provide less reliable service than parallel or feeder buses.

To the extent that the rail system operates on long headways and utilizes failure-prone equipment, reliability may be at least as big a problem as it is for buses. Overall, however, service reliability is less of an issue for rail than for bus in the context of transfer policies.

10.4 Consequences

Bus Transfers

User Satisfaction

Schedule adherence of the connecting bus affects the satisfaction of transferees in three ways. First, the variance of transfer wait time increases (by definition) as the schedule reliability of the connecting route decreases. Since variance of transfer wait time is a component of transfer level of service, user satisfaction goes down as variance increases. Second, to the extent that schedule unreliability makes it difficult or impossible to schedule arrivals at transfer points to minimize transfer waiting time, this also decreases user satisfaction.

The third effect is more subtle. Schedule unreliability leads to unequal headways between different buses on a route. Passengers waiting to transfer are more likely to arrive during the longer headways, which means, on average, they have longer to wait. Hence, expected transfer wait time increases with schedule unreliability even if average headways stay the same. This "random incidence paradox" is another reason why transfer user satisfaction drops as schedule unreliability increases. This drop in user satisfaction applies equally to transferring and nontransferring riders alike.

In terms of market segments, passengers transferring on their journey to work are most likely to have their user satisfaction negatively impacted by schedule unreliability. Work trips typically have a prespecified arrival time. Transfer time variance which causes passengers to miss their work starting times or schedule a large amount of slack time for their travel so that they arrive early most of the time lowers user satisfaction considerably. The user satisfaction of elderly transferees is also reduced by schedule unreliability, since they generally place a high disutility on long transfer times which are tiring and stressful.

Ridership and Revenue

Ridership, and hence revenue, from transferring passengers can be expected to decrease with user satisfaction as schedule adherence decreases. Schedule unreliability may cause current transit riders to stop transferring or not ride at all because they would have to transfer to an unreliable bus. Operators are generally unsure about the magnitude of these transfer-related ridership effects. It should be noted that transit service reliability (e.g., "arrive when planned") usually ranks as the most important level-of-service attribute (or second to "arrive without accident") in transit attitudinal studies.[1] However, measurement problems have precluded using reliability as a variable in any (modeling) study to date which would allow a quantitative estimate of the effect of reliability on transit patronage to be made.

Costs

A detailed examination of the costs of various remedial actions for schedule unreliability is outside the scope of this study. It is clear that strategies such as having extra buses standing by for insertion into the schedule at terminal or intermediate points leads to the largest increase in costs, while skip-stopping and first-bus passing involve little or no additional cost. A complete analysis of all of the consequences of these strategies is well worth a study of its own, as well as experiments and demonstrations.[2]

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[1]See, for example, Stanley J. Hille and Theodore K. Martin, "Consumer Preference in Transportation," _HRB_ _Record_ 197 (1967).

[2]See Sections 3, 6, and 7 in Abkowitz _et_ _al_., _op_. _cit_.

Rail Transfers

The above discussion of the consequences of bus service unreliability applies in its entirety to rail service unreliability as well. In addition, there is one effect of rail service unreliability which occurs at stations where bus service is schedule-coordinated with outbound commuter rail service in the evening. In this case rail unreliability may cause a diversion of riders who would otherwise be picked up at the station by automobiles to buses. This effect occurs because of the reluctance of the potential auto driver to meet a train which may be indefinitely late in the presence of a reliable bus service alternative.

10.5 Synthesis

The tradeoff between the costs and benefits of improving service reliability must consider both transfer- and nontransfer-related benefits. The direct transfer-related benefits of reduced transfer variance and expected transfer wait time are almost always dominated by the nontransfer effects. Therefore, the direct transfer-related benefits of improving schedule reliability are comparatively less important in the decision to implement reliability control strategies.

Nevertheless, there can be significant indirect transfer-related benefits. In the case of a simple bus/bus timed transfer, for example, if the originating bus is late, then the transfer cannot be made without holding the connecting bus (see Dynamic Control, Chapter 8). Thus, service reliability is necessary for timed transfers to work, and an improvement in reliability will decrease the operator effort and costs.

This principle holds for many transfer options which depend on having at least a minimum level of schedule coordination to maximize their user satisfaction impacts and

minimize their cost impacts. As outlined in the previous chapter, pulse scheduling can only attract ridership if the transferring passenger can be assured of making his connection. Under dynamic control a bus can wait only about 5 minutes before the strategy becomes infeasible due to operational perturbation and the costs of extra layovers. To be effective, schedule coordination of bus/rail and rail/rail transfers as well as bus/bus transfers also depends on service reliability.

Schedule unreliability is thus a major constraint on the transfer components that can be utilized in a transit property's overall transfer policy. If unreliability is too high, several other operator actions regarding transfers are likely to meet with limited success. Since the consequences of options such as schedule coordination and pulse scheduling can be quite large, minimizing unreliability for the purpose of aiding transfers may in fact be an important objective.

Chapter 11
SERVICE FREQUENCY ON CONNECTING ROUTES

11.1 Introduction

Service frequency, like schedule adherence, is an important component of transit level of service which has broad consequences extending far beyond its impact on transfers. Increasing the frequency of service on a connecting route with good schedule adherence should decrease the transfer wait time. Hence, service frequency can be an important part of a transfer policy.

Section 11.2 explores current practice relative to the influence that bus service frequency has on transfer-related issues. Section 11.3 compares typical bus frequencies to typical rail frequencies with the viewpoint of setting transfer policy. Section 11.4 examines the several types of consequences of connecting vehicle service frequency, paying special attention to the role of expected transfer wait time in determining user satisfaction. Finally, Section 11.5 presents conclusions concerning the applicability of other transfer policy options given different levels of effective service frequency.

11.2 Current Practice -- Bus

Frequency of service on a particular bus route is typically set by balancing user-side factors, such as potential and actual demand, against producer-side factors, such as cost and availability of buses and labor. Other considerations, including clock-face or policy headways, or length of routes, may also influence service frequency. The important issue to be addressed in this section is the effect of service frequency on the connecting route on transfer-related issues and vice versa.

The reduction of average transfer wait time due to a higher frequency is, of course, the direct effect of service frequency on transferring passengers. However, from the point of view of the operator, people transferring or potentially transferring to a connecting route may be of less interest than nontransferring riders. Since transferring passengers are normally far from a majority of passengers (see Chapter 4), operators usually raise or lower service frequency in response to nontransfer-related factors.

The important exceptions to this rule arise when other transfer options are implemented. By definition, most (though not all) forms of through-routing, schedule coordination, and timed transfers require that the frequencies of two or more routes be matched or at least made even multiples of each other. The operator must therefore make a choice between implementing the transfer option or maintaining the service at its original frequency. As can be seen from the earlier chapters, many operators are willing to adjust frequencies for the sake of transfers. Generally, these adjustments are not large, and fall within the range of frequencies that the operator might reasonably use if he was not implementing the transfer policy option.

An example of this is the set of actions taken in connection with pulse scheduling (Chapter 9). The adjustments in frequency made to implement pulse scheduling can affect all routes, which would not happen unless service frequency was being influenced by transfer-related issues.

On the other hand, none of the timed transfer properties interviewed adjusted frequencies very far from where they would have been if the transfer option was not used. Fifteen-minute headways were not reduced to half-hour headways, nor were routes with hour headways raised to half-hour headways. The changes made were much smaller. The same holds true for the other transfer options. Thus, transfer-related effects can have some indirect effect on service frequencies but, overall, single route-level demand-supply considerations will usually predominate in practice. Since it has been shown that different transfer policies can affect riding by generally no more than 5 to 10 percent, this practice appears reasonable except in special circumstances.

11.3 Current Practice -- Rail

Rail frequencies, except in the case of commuter rail, tend to be higher than bus frequencies. In the evening, the typical ratio is two or three trains to every bus on individual connecting routes. During peak hours, rail and bus frequencies are closer, but rail frequencies are still generally higher. Of course, where several bus routes serve a rail station, the effective arrival rate of buses can be as high, if not higher, than the rail frequency.

Rail frequencies are almost never changed for the purpose of implementing a particular transfer policy option, for several reasons. First is the typically high frequency of rapid rail, which tends to make other transfer policy options unnecessary when rail is the connecting vehicle. Second, it is often difficult or impractical to change headways, especially on systems where much interlocking of different routes goes on. Frequency increases may be very costly in terms of manpower and equipment, while frequency decreases are often constrained by demand levels. Finally, if the buses and trains are scheduled by different people, coordination between the two groups regarding transfer connections may be difficult or impossible. Overall, bus schedules are almost always adjusted to fit rail schedules for transfer policy purposes, and not the other way around.

11.4 Consequences

All discussion in this section applies to both bus and rail transfers.

Costs

The cost of increasing service frequency is quite significant. Costs will differ from property to property, but running one extra bus on a route for 12 hours a day each weekday at $20 per bus-hour will cost approximately $60,000 per year. Furthermore, buses may not be available to raise service frequency without capital expenditures. Rail frequencies are difficult to increase for the same reason, plus the added constraint of track capacities. These are reasons why large changes in service frequency are typically only made in response to overall demand, and not simply transfer demand.

User Satisfaction

The most immediate and obvious transfer-related effect of changing service frequency is the alteration of expected transfer wait time. As service frequency increases, expected transfer wait time will decrease significantly unless bunching of vehicles occurs. Several operators report that bunching puts effective practical limits on how low expected transfer wait time can go unless mitigating strategies are undertaken.

User satisfaction rises as expected wait time decreases. It is generally accepted that wait time, of which transfer wait time is one example, is more onerous than in-vehicle travel time. Indeed, transfer wait time is believed by many operators to be more onerous than other kinds of wait time, even when shelters and high security are provided. This is likely to be true because the transfer point is not near the trip's origin or destination, leaving the rider much more sensitive to the wait time. This suggests that kiosks selling newspapers and refreshments, message boards, etc., may be particularly valued at transfer points.

Ridership and Revenue

The effect of connecting-route service frequency on transit ridership, and hence revenue, is very important. Ten- to fifteen-minute headways are believed by many operators to be a threshold at which transfer ridership increases significantly, since transferring is extremely burdensome on the rider with larger, uncoordinated headways. Futhermore, if the headways on a connecting route dropped from 30 minutes to 15 minutes, this would induce a greater percentage increase in the rate of transfers to the route than a drop from 10 to 5 minutes. This is generally supported by several case studies of bus demand elasticities, which support the theory that

demand elasticities are higher where level of service is lower (e.g., that further headway reductions on an already high-frequency route have little effect on ridership).[1]

11.5 Synthesis

Changing service frequency has overall consequences which can dominate the transfer-related effects. However, as outlined, implementation of a transfer policy option can usefully entail adjustments to frequency. This section points out the reverse, i.e., the major effect of service frequency on determining useful transfer options. In order to draw such conclusions, the concept of "effective service frequency" is employed. Effective service frequency is defined for a particular trip in terms of the number of routes traveling over the link to the desired destination, their scheduled headway, and the amount of schedule unreliability and bunching that exists. Effective service frequency measures the amount of time a passenger can expect to wait before a vehicle that he can use arrives. For instance, in the case of collector/distributor transfers in the CBD, effective service frequency may be quite high because many bus routes use the same streets.

An effective service frequency of every 10 to 15 minutes is widely regarded as a threshold, shorter than which no other transfer scheduling options are generally needed. It is important to emphasize that effective service frequency is the key, and not nominal schedule frequency on one particular route.

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[1]See, for example, Carstens and Csanyi, op. cit.; and Kemp, "Policies To Increase Transit Ridership" (Washington, D.C.: Urban Institute, September 1977).

The existence of such a threshold is quite plausible. No transfer scheduling option, including pulse scheduling, can consistently guarantee a transfer wait time (not necessarily out-of-vehicle) of less than 5 minutes, because layovers must usually be that long to ensure that transferring passengers make connections. Hence, application of scheduling options to a route with 10-minute headways cannot significantly decrease expected transfer wait time. Since user satisfaction cannot be increased significantly, service frequencies on connecting routes of under 10 minutes tend to eliminate the need to implement other scheduling options.

Chapter 12
TRANSFER CHARGE

12.1 Introduction

The transfer charge is the amount of additional money, over and above the basic fare, which a passenger pays to transfer to a second vehicle. Different classes of passengers (e.g., the elderly) may pay different transfer charges. In practice, the transfer charge takes on any value between zero and full (or regular) fare. The former corresponds to free transfers, while the latter corresponds to not granting reduced fare transfers and dispensing with associated mechanisms for identifying transferring passengers. Choosing a transfer charge is clearly a key element of a transfer policy.

Section 12.2 examines the transfer charges currently in use for bus/bus transfers, and the rationale behind them. Section 12.3 then examines the transfer charges for bus/rail and rail/rail transfers, and the factors which cause them to be set at particular levels. Section 12.4 reviews the consequences of different transfer charges. Primary attention is given to bus/bus transfers, with a separate subsection

pointing out the unique consequences associated with bus/rail and rail/rail transfer charges. Finally, Section 12.5 analyzes the tradeoffs among equity, ridership and revenue, and suggests guidelines for setting the transfer charge.

12.2 Current Practice -- Bus

The majority of U.S. transit properties have bus/bus transfer charges of $0.00 or $0.05 for full-fare riders. Very few properties have transfer charges between these two (i.e., not free or single coin), although several years ago there were some which charged $0.02 or $0.03 for transfers. Surprisingly, relatively few properties have full-fare transfers. Therefore, the granting of reduced-fare transfer privileges is very widespread. Figure 1-1 in Chapter 1 shows the transfer charge, broken down by segmentation criteria, on each interviewed property.

There is no consistent trend in transfer charges over recent years. Some properties have raised the charge slightly, e.g., from $0.02 to $0.05. Other properties have lowered their transfer charge. On average, nominal (and certainly real) transfer charges seem to drift downward, although this tendency is neither pronounced nor universal.

With some exceptions, most properties have uniform transfer charges across their entire system (not including express and other special routes). Toledo, an exception, has nonzero overall transfer charges but allows free transfers to and from the most highly utilized crosstown line. This is done to reduce transferring in the CBD, particularly by school children. Another special case is New York City which, for historical reasons, has some transfer points where transfers are free and other transfer points where transfers are $0.25 (formerly but not presently full fare).

Variations in transfer charge often occur where a regional transit authority has jurisdiction over several formerly independent bus systems. In this case, transfer charges for intracarrier transfers may differ from transfer charge between carriers. The Pioneer Valley Transit Authority (Springfield, Massachusetts) has transfer charges ranging from $0.00 to $0.10 for various intracarrier transfers, but a uniform $0.10 intercarrier transfer charge. In 1976, the Regional Transportation Authority (Chicago, Illinois) introduced a Universal Transfer which permits transfers between different carriers. The cost of this transfer ranges from $0.10 to $0.30, depending on the basic fare of the carrier issuing it in such a way that the total trip cost (basic fare plus transfer) equals $0.60.

A variety of rationales exist for setting the level of the transfer charge. These reasons are listed here in descending order of importance.

- Historical;
- Transfer abuse;
- Political/equity considerations (including encouraging/not penalizing transfers);
- Revenue;
- Public relations;
- Decreasing bus running time; and
- Others (e.g., lack of transfer system).

For many properties, the main reason for a particular transfer charge is historical precedent. Most properties which use this rationale also have other justifications. However, it is clear that many properties have not recently given serious consideration to the level of their transfer charge.

There are several reasons why this may be so. In the case where a public transit authority has taken over a private carrier, the transfer charge previously set by the private

operator may have been adopted by the public authority. In comparison with other needed changes, the transfer charge may seem to be of low priority. Another possible reason for perpetuation of historical precedence is simple inertia and the difficulty of changing what is already there. A particular charge for transfers is often viewed as part of the "framework" of transit. The transfer charge may therefore be virtually fixed within the context of operator decisions.

Reduction of transfer abuse is the second most commonly cited justification for setting the transfer charge. A nonzero transfer charge reduces the "resale" of transfers at a price below that of a full fare or giving them away to friends and relatives. Operators believe that fewer people would take transfers with the intent of later distribution if they had to invest $0.05, for instance. It is not clear how prevalent transfer abuse of this type is. Operators who perceive transfer abuse as important all come from properties with a nonzero transfer charge. Systems with no transfer charge may be aware of or choose to ignore whatever transfer abuse does occur.

Another important factor influencing operator attitudes towards transfer abuse as a determinant of transfer charge is the background of the individual. Operations-oriented individuals are much more likely to be concerned with transfer abuse than those oriented towards planning or marketing. This may be because operations people have more awareness of the actual rate of transfer abuse.

A fourth popular rationale for setting the level of transfer charge involves political/equity considerations. These are typically used to justify a zero transfer charge in accordance with one or more of the following reasons:

- Desire not to penalize transfers;
- Desire to maintain low fares (including transfer charges);
- Desire to encourage transfers;
- Desire not to penalize transit dependents;
- Desire not to penalize riders from a particular geographic area;
- Desire not to penalize nonpeak users;
- Desire to subsidize long (e.g. suburban) trips; and
- Funding issues.

The most prevalent reason is not wanting to penalize riders who have to transfer. The feeling is that transfers are onerous enough without requiring people to pay for them as well. Phrased in another way, the basic fare is supposed to buy a trip from origin to destination, not a trip on a single bus, and any other policy would be unfair to transferring passengers. It should be noted, though, that no operators assert that transferring passengers should receive a lower basic fare because of the inconvenience of transfers.

Another important reason is the desire to maintain low fares as policy. Transfer charges are set at zero as part of an overall strategy, and not because transferees are seen as warranting special treatment. In contrast, some properties with grid systems are interested in encouraging transfers in particular by keeping transfers free.

An entire class of equity considerations relates to perceived differences between the types of people who transfer and the types of people who do not (see Chapter 4). Some operators feel that a transfer charge would weigh more heavily on transit dependents, who are more likely to have to transfer. On other properties, the route structure would require riders from a particular geographic area to transfer more often than

other riders. A transfer charge would then discriminate against people who live in that geographical area by forcing them to pay more. Often these two rationales overlap because transit dependents live in a particular neighborhood which does not receive direct transit service to many destinations. Equity considerations would then demand that these people not be required to pay more for transferring.

A more subtle equity question relates to discrimination between peak and nonpeak riders. Peak-hour bus frequencies are almost always higher than non-peak-hour bus frequencies at least on larger and nonpulse properties. As discussed in Chapter 11, the frequency of the connecting bus is an important determinant of transfer wait time and therefore of the burden imposed by transferring. Hence, transfers made during peak hours will be easier than transfers made during nonpeak hours. It can be argued that imposing a transfer charge would force riders transferring at different times of the day to pay the same amount for different levels of service.

An equity issue whose effects run contrary to the others involves the use of the transfer charge as a proxy for a zonal fare system. If it is assumed that transferees make longer trips than nontransferees, a non-zero transfer charge effectively prices long trips higher than short trips. While this assumption may not hold on many properties (especially those which combine long radial routes with a downtown collector-distributor system), using the transfer charge as a substitute for a zone fare has the advantage of being easy to administer. However, few properties use the transfer charge for this purpose.

The final political/equity consideration is the influence of the source of funding on the transfer charge. Deficits can be funded from several different sources: general revenues,

sales taxes, payroll taxes, community- or county-level assessments, etc. Any geographically based source of funding may constrain the distribution or pricing of services. In particular, there may be pressure to maintain the transfer charge at zero by groups who would have to transfer and who are already paying for transit through regional or local property or sales taxes. This is important in some cases, and not in others.

Revenue is cited by surprisingly few properties as a reason for having a nonzero transfer charge. The current general feeling is that the transfer charge is a matter of policy, rather than being directly related to revenues.

There are several reasons for setting transfer charges which do not fit easily into the above categories. Public relations are an important factor which lead some properties to use a zero transfer charge. These operators believe that riders are liable to view a small transfer charge as a nuisance, and to complain strenuously. Another property, Fresno, California, eliminated the transfer charge partially to reduce rider-driver arguments over the extra fare, and hence speed up the bus. Finally, Lawrence, Massachusetts has a full transfer charge solely because they lack a "good" system for handling transfer slips. Once a system is selected, the transfer charge on this property will be reduced. Figure 12-1 lists examples of properties where several of the above reasons were cited as being important in setting the transfer charge.

12.3 Current Practice -- Rail

Bus/rail and rail/rail transfer charges are considerably less uniform across different properties than bus/bus transfer charges. There are full-fare transfers, half-fare transfers,

Figure 12-1

REASONS CITED FOR BUS/BUS TRANSFER CHARGE

Reason	Example of Properties Citing Reason
Transfer abuse	Toledo Boston Lafayette Baltimore
Political/equity	Hartford Columbus Denver Lewiston
Revenue	Jacksonville Boston Pittsburgh Baltimore
Decrease bus running time	Fresno
Lack of transfer system	Lawrence

SOURCE: Operator interviews.

dime transfers, nickel transfers, and free transfers. Rail/rail transfers tend to be free, though this is not always the case. Figures 12-2 and 12-3 provide bus/rail and rail/rail transfer charge information by direction of transfer for each rail property participating in this study.

The principal reasons for setting the level of the bus/rail transfer charge are (in descending order of importance):

- Historical/institutional/political
- Revenue
- Abuse
- Equity

For most properties, key factors in determining the level of transfer charge (for bus/rail in particular) are the historical and current relationships between the bus operating authorities and the rail operating authorities, or between different rail operating authorities. If the operating authorities were originally or presently separate, then a reduced transfer charge will often not be offered. For instance, in Philadelphia the Red Arrow Division and the City Transit Division used to be completely different companies. Transfers between these two divisions were only recently offered due to problems in allocating revenue and costs.

These historical considerations tend to encompass institutional and political factors. Even where a particular transit authority includes both rail and bus lines, they are often separate divisions which have separate accounting. Moreover, the rail system is often funded on a different basis than the bus system, whether or not there are formally different operating authorities. This occurs, among other places, in Washington, San Francisco (with three distinct systems involved) and Philadelphia (both between divisions, and between SEPTA and the Lindenwold system). Political

Figure 12-2

BUS/RAIL AND RAIL/RAIL TRANSFER CHARGE
(Excluding Commuter Rail)

Urban Area	Bus to Rail Transfer Charge (cents)	Rail to Bus Transfer Charge (cents)	Base Fare (cents)
Atlanta	0	0	25
Boston	25	25	25
Chicago	10	10	50
Cleveland	10[1]	0	25 (bus)
New York	50[2]	50[2]	50
Philadelphia[3]	5	5	45
Pittsburgh	10	10	50
San Francisco	25	0[4]	25
Washington, D.C.	40	0	40

[1]Transfer charge only applies from local bus to rail.

[2]Bus/rail transfers are free at three transfer points where bus has replaced rail.

[3]Transfers between Red Arrow and City Transit Divisions are $0.30.

[4]On AC Transit, free transfers are issued at rail station. On Muni, rider pays $0.25 at rail station for two-way ticket.

Figure 12-3

COMMUTER RAIL/TRANSIT TRANSFER CHARGE

Urban Area	Commuter Rail to Transit Transfer Charge (cents)	Transit to Commuter Rail Transfer Charge (cents)	Comments
Boston	0	Full	Free only with commuter rail pass.
Detroit	0	0	Feeder bus is free with two-part rail transfer.
New York	Full	Full	
Philadelphia	0-10	0-10	Various transfer charges between commuter rail and bus.
	Half-fare	Full	Transfers from Lindenwold line.
Pittsburgh	10	Full	
Westport	Full	Full	Conrail commuter trains.

constraints on funding may often dictate a particular level of transfer charge, regardless of arguments about revenue, abuse, or equity.

These latter considerations can, however, be important. Both New York and Boston, cities with full-fare bus/rail transfer charges, also have chronic deficit problems. Such problems form a crucial part of the argument whenever the possibility of lowering bus/rail transfer charges arises. The decrease in revenue which would result from reducing the transfer charge is a key consideration in these cases.

Transfer abuse is another reason for setting the transfer charge at a nonzero level. When Philadelphia had a zero transfer charge there was a thriving black market in transfers. Similarly, one reason for Boston having a full transfer charge is to eliminate the possibility of transfer abuse completely. Bus/rail transfer systems which depend on automatic dispensers in rail stations are particularly vulnerable to abuse. It should be pointed out, though, that political considerations can hold the transfer charge at a particular level regardless of the amount of abuse. For instance, the transfers between AC transit and BART in San Francisco are subject to a large amount of abuse, but a half-fare transfer charge is retained.

Equity appears to be the least important reason for setting the level of the transfer charge for bus/rail transfers. One reason for this appears to be the difficulty in deciding on what equity means in a given situation. For example, one operator may state that "a transit fare should buy a trip from origin to destination." Another version of equity might be that longer trips requiring transfers should be more expensive. A third version would be that the suburbs who finance the system should receive low fare service.

Figure 12-4 lists examples of properties where each of the above reasons were cited as being important.

Figure 12-4

REASONS CITED FOR BUS/RAIL AND RAIL/RAIL TRANSFER CHARGE

<u>Historical/Institutional/Political Reasons</u>

Atlanta
New York
San Francisco
Washington

<u>Revenue</u>

Philadelphia
Boston
New York
Pittsburgh

<u>Abuse</u>

Philadelphia
Boston

<u>Equity</u>

Atlanta

Some additional considerations may also go into setting the rail transfer charge. Rail/rail transfers tend to be free, partly because rail transfers are usually made within the same station structure (though this is not true in Chicago) and partly because most rail properties have only a few rail/rail transfer points. Of course, alternative arrangements are possible. For example, fare gates can usually be placed in a manner which allows a charge to be placed on rail/rail transfers. While many fare gates may be required to handle peak transfer flows, the current layout of rail stations generally does not necessitate free transfers. Such policies therefore result from decisions made by transit system operators.

12.4 Consequences

Bus Transfers

Costs

The only cost consequences from a transfer charge result from the possible slowdown in bus passenger entrance and the minor cost of counting and handling the additional revenue. In addition, there is a cost of administering reduced fare or free transfers (normally) through a system of transfer slips. However, these costs are separable. They are addressed in the next chapter, along with the other consequences of using transfer slips.

The cost of slowing down the bus to process the transfer charge results both from the need to pay a charge and from disputes which may develop between drivers and passengers over transfer abuse. Several operators view this as a significant factor affecting the level of the transfer charge. A small but nonzero transfer charge probably slows down buses the most,

since it involves the exchange of both a slip and extra money. A full fare transfer charge slows buses down the least since no transfer slips are involved. A zero transfer charge can be assumed to have an intermediate effect. However, hard data concerning how much the transfer charge slows down service and increases vehicle hours are not available.

<u>User Satisfaction</u>

The user satisfaction consequences of bus/bus transfer charges are not perceived to be significant by operators. In general, operators rely on user complaints to gauge satisfaction, and few receive complaints concerning the level of the transfer charge.

On the other hand, there is considerable evidence which suggests that user satisfaction drops as the bus/bus transfer charge goes up. First, political/equity considerations would not be important in setting transfer charges unless it was assumed that the level of transfer charge influences user satisfaction. Second, by their forecasts of the effect of transfer charge on ridership (see below), operators do link the transfer charge and user satisfaction. Third, transferees are, by definition, made worse off by extra cash expenditures. Hence, it must be concluded that user satisfaction is in fact lowered when the transfer charge is raised.

There appear to be two factors which determine how much user satisfaction is affected by a change in bus/bus transfer charge. One is the disutility associated with charges for different user groups. Low-income riders, for instance, will be affected more by a given level of charge than riders with higher incomes. The other factor is "justifiability," the feeling among riders that the charge is fair and has a purpose (e.g., to make longer trips cost more). In the absence of such a justifiable purpose, riders often resent the charge. In that

sense, a nominal transfer charge (e.g., $0.05) runs a high risk of appearing to have only nuisance value. However, transferees tend to adjust and become inured to any level of transfer charge, and not complain directly to operators.

Ridership

Both total bus ridership and the bus/bus transfer rate appear to be sensitive to the level of transfer charge. In the cases discovered in this study where the transfer charge was changed without making other major changes (e.g., in level of service), total ridership increased as the transfer charge dropped. However, the magnitude of the change was strongly influenced by site-specific factors (e.g., existence of a subway system).

The transfer rate is also related to the level of transfer charge. Figure 12-5 lists all properties participating in the study with transfer rates known to be over 20 percent. Most have a zero transfer charge. On the other hand, as shown in the figure, there are several properties with transfer rates under 10 percent that have a nonzero transfer charge. It is possible that 1) nonzero transfer charges discourage transfers or 2) properties whose route structure produces a high transfer rate experience pressure to lower the charge. It is reasonable to conclude that site-specific considerations are probably most important in determining the amount of transferring exhibited at any one time on any particular property.

Different types of riders and trips will be affected differently by a change in transfer charge. Captive riders, by definition, have their riding patterns altered least by an increase in transfer charge. Shopping and other discretionary trips would be most discouraged. Distributor/collector transfers would probably be discouraged as well, depending on the size of the CBD.

Figure 12-5

RELATIONSHIP BETWEEN TRANSFER RATE AND TRANSFER CHARGE

Transfer Rate	Property	Transfer Charge (cents)
More than 20 percent		
	Eugene	0
	Fresno	0
	Brockton	0
	Everett	0
	Charleston	0
	Washington	0
	Columbus	0
	Atlanta	0
	Portland, OR	0
	San Francisco	0
	Lewiston	0
	Buffalo	5
	Lafayette	5
Less than 10 percent		
	Lawrence	30
	Toledo	5
	Pittsburgh	10
	Portland, ME	0
	Duluth	0
	Hartford	0

SOURCE: Operator interviews.

The ridership effects of transfer charge can be explored further through use of demand elasticities. Many studies exist which have produced fare elasticities, but none are known which deal only with transfer charges. Typically, elasticity estimates with respect to total transit cost range from -.1 to -.58, with an average of -.3. It is useful to use the wide range of estimates to illustrate changes in ridership which would result from various changes in transfer charge and base fares. These are shown in Table 12-1. It can be seen that with the more generally applicable elasticity value of -0.3, total ridership can decrease by 1.1 to 10.0 percent with the transfer charge increases shown in the table. With the extreme elasticity value of 0.58, the ridership decrease could be as high as 19 percent.

Revenue

Revenue will typically increase as the bus/bus transfer charge goes up, due to the generally inelastic demand for transit. The ridership examples calculated above from various elasticity estimates can be used to show how total revenue and transfer revenue can change with changes in the transfer charge. Table 12-2 describes the revenue consequences of various scenarios. In most cases examined, an upward change in the transfer charge did not cause ridership to fall enough to cut revenue.

Total revenue from transfer charges can be quite substantial. On several properties (excluding New York City), transfer revenues run as high as $800,000 with only a $0.05 transfer charge. Transfer revenue can also be described as a percentage of basic fare revenue. By definition, on properties with a full transfer charge and a transfer rate of 20 percent, transfer revenue would be 20 percent of basic fare revenue, or 16.7 percent of total revenue. For properties with a reduced

Table 12-1

EFFECTS OF CHANGES IN TRANSFER CHARGE ON TOTAL RIDERSHIP AND TRANSFER RATE[1]

			Low Elasticity (-.1)		Medium Elasticity (-.3)		High Elasticity (-.58)	
Initial Transfer Charge (cents)	New Transfer Charge	Base Fare	Change in Total Ridership (percent)	New Transfer Rate (percent)	Change in Total Ridership (percent)	New Transfer Rate (percent)	Change in Total Ridership (percent)	New Transfer Rate (percent)
0	5	25	-0.6	19.6	-2.0	19.0	-3.9	18.1
0	25	25	-3.3	18.4	-10.0	14.9	-19.3	9.5
5	25	25	-2.2	18.9	-6.7	16.7	-13.0	13.3
0	5	40	-0.4	19.8	-1.3	19.4	-2.4	18.8
0	10	40	-0.8	19.6	-2.5	18.8	-4.8	17.6
5	10	40	-0.4	19.8	-1.1	19.5	-2.1	19.0
5	25	40	-1.5	19.3	-4.4	17.8	-8.5	15.7

[1]Initial transfer rate assumed to be 20 percent.

Source: Charles River Associates, May 1979.

Table 12-2

EFFECTS OF CHANGES IN TRANSFER CHARGE ON TOTAL REVENUE AND TRANSFER REVENUE[1]

				Low Elasticity (-.1)		Medium Elasticity (-.3)		High Elasticity (-.58)	
Initial Transfer Charge (cents)	New Transfer Charge	Base Fare	Initial Ratio of Transfer Revenue to Total Revenue	Change in Total Revenue (percent)	New Ratio of Transfer Revenue to Total Revenue	Change in Total Revenue (percent)	New Ratio of Transfer Revenue to Total Revenue	Change in Total Revenue (percent)	New Ratio of Transfer Revenue to Total Revenue
0	5	25	0	+3.5	.038	+2.6	.037	+1.2	.035
0	25	25	0	+16.0	.155	+8.0	.130	-3.2	.087
5	25	25	.038	+12.8	.159	+7.7	.143	+0.4	.117
0	5	40	0	+1.9	.024	+1.7	.024	+0.8	.023
0	10	40	0	+4.4	.046	+3.1	.045	+1.4	.042
5	10	40	.024	+2.1	.047	+1.6	.046	+0.9	.045
5	25	40	.024	+8.4	.108	+5.5	.100	+1.6	.089

[1]Initial transfer rate assumed to be 20 percent.

Source: Charles River Associates, May 1979.

transfer charge, this fraction can be easily calculated using the applicable charge and the transfer rate. For those properties with a nonzero transfer charge participating in this study, transfer revenue as a percent of basic fare revenue averaged approximately 2 percent.

Rail Transfers

The only direct cost consequences which result from having a nonzero bus/rail transfer charge are the minor costs associated with processing additional revenue. There may also be costs associated with the transfer slip method used (treated in the next chapter).

The user satisfaction consequences of a reduced bus/rail transfer charge are basically the same as those for bus/bus transfer charges. User satisfaction must go down as the transfer charge goes up, with the amount of change depending on the income of the user and the degree of "justifiability" of the transfer charge. Since bus/rail transfers involve a change of mode, and tend to be part of longer trips than bus/bus transfers, riders view them as being relatively justified. Hence, bus/rail transfer charge increases may decrease user satisfaction less than would an increase in bus/bus transfer charge.

Ridership is definitely affected by bus/rail transfer charges. This is demonstrated graphically on those properties such as AC Transit (San Francisco) and Washington which have asymmetric transfer charges for bus/rail transfers (full fare bus to rail, free rail to bus). On these properties, the number of people who transfer from rail to bus is significantly greater than the number who transfer bus to rail (i.e., 17 percent more rail to bus than bus to rail transfers in Washington). Despite possible biases in favor of evening-only feeder bus use described in Chapter 10, these data tend to indicate the importance of the transfer charge.

using demand elasticities, the theoretical effects of bus/rail transfer charge changes can be calculated in the same manner as before (see Table 12-1). Revenue effects follow likewise (see Table 12-2).

In general, decreasing the bus/rail transfer charge should decrease revenues, both directly because of inelastic demand, and indirectly because of transfers being abused. Losses due to abuse are not inconsequential, and may amount to several thousand dollars per day when transfers are free (much less for nonzero charge transfers). Clearly, the consequences of bus/rail transfer charges can be quite significant.

12.5 Synthesis

Each of the three levels of bus/bus transfer charge -- zero, small but nonzero, and full -- seem to be stable and viable, at least over the foreseeable future. Most transit systems employing each type have no plans to change their transfer charge. In fact, Boston, which is one of the few cities with a full transfer charge, recently reaffirmed its commitment to full charge transfers by eliminating reduced fare transfers for school children and on some outlying suburban routes.

When changes in transfer charges are considered, two sets of tradeoffs are important. The first is the nuisance versus abuse tradeoff, which weighs the abuse from free transfers against the nuisance value of a small but nonzero transfer charge for riders. As outlined earlier, abuse is a particularly important factor in rail transfers. Employing a full transfer charge would evade this tradeoff altogether.

The second major tradeoff involves equity, ridership and revenue. Equity/political reasons usually suggest that the transfer charge be set at zero. However, if the transfer

charge is a proxy for a zonal fare, then equity may dictate some sort of nonzero transfer charge. This reasoning is especially true for bus/rail transfers.

If equity is considered to be a secondary issue, then ridership and revenue become important considerations. Maintaining a low base fare to encourage total ridership may call for relatively high transfer charges for revenue reasons. A large deficit may also necessitate raising transfer charges to raise more revenue, which discourages transferring.

This above discussion should confirm that the selection of the transfer charge depends on the operator's goals. There is no transfer charge which is optimal for every situation. The tradeoffs which apply on each property must be assessed independently.

Chapter 13
TRANSFER SLIPS

13.1 Introduction

Transfer slips are the principal method for offering reduced-fare transfers. These slips are intended to identify a passenger as one who has already boarded a vehicle on his/her trip and (within stated time and directional limitations) is entitled to board subsequent vehicles at reduced fare. Passengers wishing to transfer receive a slip from the driver of their bus or by some other means. These passengers then turn them in to the driver of the connecting bus. Clearly, issues related to transfer slips are only relevant if the operator wishes to charge less than full fare for transfers.

Several issues related to transfer slips are outside the scope of this study. The effects of varying the temporal and directional restrictions on transfers are not analyzed, nor are the internal management and administrative procedures associated with controlling transfer slips. In addition, this chapter will note the different kinds of "hardware" that can be used for transit transfers, i.e., different types of transfer slips, magnetic cards, etc., but will not evaluate their

relative merits in detail. These subjects are all highly interesting and sometimes complex but are left to future research.

Section 13.2 examines current practice regarding transfer slips for bus transfers and their substitutes, while the current practice for rail transfers is described in Section 13.3. Section 13.4 examines the consequences of using transfer slips. Finally, Section 13.5 reviews situations where different mechanisms for offering reduced-fare transfers are applicable.

13.2 Current Practice -- Bus

Most transit properties use transfer slips to provide reduced-fare bus/bus transfers. Transfer slips are thought to be an integral and necessary component of the overall transit system. Few operators perceive any significant problems with their usage.

Most transit properties with reduced but nonzero bus/bus transfer charges have passengers pay for transfers when they receive the transfer slip on the first bus. A small number of systems (e.g., Buffalo) require payment of the transfer charge on the second bus. This involves two separate monetary transactions -- one to pay the basic fare and receive the transfer slip, and one to return the transfer slip and pay the small transfer charge. This arrangement does not cut down on transfer abuse, but it does eliminate user dissatisfaction caused by investing in transfers and then possibly not using them.

The use of transfer slips to gather ridership information varies considerably between properties. Some systems, especially those with zero transfer charge, maintain very loose administrative controls on transfer slips. These systems

generally know the number of slips which are issued to drivers, and sometimes how many are issued to passengers, but not how many are actually used by route, day, etc. Instead, these properties and others may make annual or quarterly counts of their transfers, on either a route-by-route or a systemwide basis. Properties with a nonzero transfer charge tend to keep better track of their transfer slips, often having their drivers count the slips as they collect them. At least one property, Toledo, weighs the transfer slips daily to estimate their number.

One property participating in the study (Haverhill, Massachusetts), offers free transfers without utilizing transfer slips or <u>any</u> substitute. Haverhill's transit system has only three buses, and they are all on a pulse schedule. Since the buses are all at the transfer point at the same time, the drivers are able to see whether people are transferring from the other buses, and they can consult with other drivers in the event of a dispute. It should be noted, though, that the transit authority which administers the Haverhill system is planning to institute transfer slips in the near future.

Some systems (including Everett, Washington) use daily passes instead of transfer slips. These paper slips, generally sold for twice the basic fare, allow unlimited riding for an entire day. For the purposes of transferring, daily passes function much like free transfer slips with no directional or temporal limitations.

13.3 Current Practice -- Rail

A variety of methods are available for offering reduced charge bus/rail transfers. Figure 13-1 lists the methods utilized by the properties participating in this study, together with examples of cities which use them.

Figure 13-1

BUS/RAIL TRANSFER METHODS

Method	Used By
• Transfer slip issued by bus driver or change booth clerk, collected by same	Cleveland, Philadelphia, Chicago
• Commuter rail pass good on transit	Detroit
• Two-part rail pass issued on train or in station, one part good for bus trip away from rail and other part good for bus trip toward rail	Detroit, San Francisco
• Transfer to bus dispensed from machine in rail station at destination	AC Transit
• Transfer to bus dispensed from machine at originating rail station	Cleveland, Philadelphia, Washington, Atlanta
• Direct paid area for bus/rail transfers	Atlanta, New York
• Magnetic card for transfer to rail obtained on bus	Atlanta
• Rail to bus transfer obtained from original bus driver	Atlanta

The first method utilizes a transfer slip issued by the bus driver or change booth clerk and can be used for both bus/rail and rail/rail transfers. Indeed, this method is just an extension of the way that transfer slips are commonly handled for bus/bus transfers so it may require few changes in operating procedures.

Having a commuter rail pass which is valid on rail or bus transit is a simple way of providing free transfers for regular commuter rail riders. This method also has the effect of promoting the sale of passes for commuter rail riders.

The third method, the two-part transfer slip good for one bus trip from and one bus trip to the train station, is a complicated procedure used largely for institutional reasons. In Detroit, for example, SEMTA wanted to offer free feeder bus service for commuter rail riders, but felt it unwise to have bus drivers issuing transfer slips which were valid on the train. The decision was therefore made to have the train personnel issue two-part transfers. In practice, however, the train personnel (who are not employees of SEMTA) dislike handling the transfer slips.

The fourth method, transfers from rail to bus dispensed at rail destination stations, utilizes "parking lot-type" ticket spitters in the fare paid area. This method encounters problems of abuse, since the transfer slips are free, and dispensed mechanically.

A more prevalent method is to have the transfers to bus from rail dispensed in the originating rail station, with the proviso that they are not valid at that station. These can be issued either by a clerk or by machine. Use of a clerk could drastically reduce abuse. In Atlanta, the machine issuing the transfer slips will be tied to the entering fare gate, so that the number of slips issued does not exceed the actual number of

potential transferees. By issuing transfer slips at the originating station, it may be possible to take advantage of the usually even flow of incoming passengers, and provide the same number of transfer stops with fewer machines than would be needed at destination stations (which must handle pronounced peaks in volume).

A sixth method is to provide paid areas where free bus/rail transfers can be accomplished without transfer slips. This option will be used in Atlanta at several rail stations and is already employed in New York at the terminus of one rail line.

For passengers on buses which do not go into a paid bus/rail transfer area, Atlanta has magnetic cards (costing one cent apiece) which are accepted by the automatic fare collection machinery. These cards also permit a passenger to obtain a transfer for the return trip. However, those passengers who go through a paid area do not pass through a fare gate and cannot obtain a rail-to-bus transfer in this manner. They must use still another procedure for transferring by obtaining rail-to-bus transfers from the original bus driver.

13.4 Consequences

Bus Transfers

Costs

Transfer slips are generally not perceived to have major cost consequences. The costs of administering transfer slips are usually treated as part of the overall administration effort. Estimates of the time spent administering and

controlling the slips typically range from "a couple of person-hours per day" (on a system issuing 550,000 transfers per year) to approximately one person full-time (on a system issuing 725,000 transfers). At the high end of the spectrum is the Massachusetts Bay Transportation Authority (Boston), which several years ago estimated the cost of issuing free transfers on buses to bus riders transferring to the subway, who then transferred to other buses. The mechanics of this transfer would be the same as for ordinary bus/bus transfers, and the cost, not counting lost revenue, was estimated at $1 million. Most of this cost was attributable to the 10-minute turn-in time allowed each driver at the end of his shift to account for transfers. Other labor costs arose from personnel needed to administer and issue the transfers. The transfers themselves were estimated to cost approximately $100,000 per year. These estimates provide some idea of the possible maximum costs of transfer slips.

Use of transfer slips may also decrease the rate at which passengers enter the bus, thus decreasing average running speed and increasing vehicle hours. Properties on which payment for the transfer occurs in the connecting bus may be particularly burdened by this effect. Disputes between passengers and drivers over transfer privileges also result in slower speeds, as well as bad public relations. These delays are key reasons cited by operators who wish to eliminate transfer slips. Finally, some time and cost may be associated with counting the slips, but if they are counted infrequently, the total impact will not be significant.

User Satisfaction

Transfer slips appear to have no major direct consequences on user satisfaction. Any disutility associated with handling the slip is self-limiting, since an individual always has the option of not using it and paying full fare for the transfer.

Paying for transfer slips on the originating bus can have a minor negative impact on user satisfaction if schedule reliability on the connecting bus is poor. If the ultimate destination is not far from the transfer point (as in the case of distributor/feeder transfers) the individual who has already invested money in a transfer slip may be tempted to walk and lose the investment rather than wait an indeterminate amount of time. When this occurs, there are apt to be many complaints from frustrated transferees. Generally, however, the impacts that transfer slips have on user satisfaction are minor.

Ridership and Revenue

Since transfer slips have little impact on user satisfaction, they will not significantly affect ridership and revenue directly. Their only impacts will be the indirect effects which arise from their use in allowing properties to offer reduced-fare transfers (see the previous chapter).

Rail Transfers

In contrast to bus/bus transfer slips, methods for providing bus/rail transfers generally have quite significant cost consequences. Rail stations must handle large volumes of passengers. Since transfer slips of the ordinary bus/bus type must be accepted by a person for validity checks, a mere extension of bus/bus transfer procedures to bus-to-rail transfers will not work without extra cost.

The principal cost consequence of bus/rail transfers in most cities therefore comes from the need to add gatemen and change clerks in the rail stations to issue and collect transfers. A 1976 Boston study estimated the total additional labor cost of bus/rail transfers to be $1.95 million annually,

including bus driver time for accounting for the transfers).[1] Those cities with only rail-to-bus transfers, of course, need not worry about the latter cost. Other costs include the transfer slip itself (estimated as a yearly total of $225,000 in Boston, and one cent per magnetic card in Atlanta), the transfer-dispensing machines (where used), and the extra cost of station construction when a paid area is included.

The method of providing bus/rail transfer slips also has a significant indirect effect on user satisfaction, ridership and revenue because of the constraints which it places on the level of transfer charge. Washington and San Francisco, with automated fare collection equipment, have found it impossible to offer free bus-to-rail transfers. Indeed, in Washington free bus/rail transfers would be offered in both directions if not for this problem; therefore, riders experience a higher total fare (and thus a lower user satisfaction) as a consequence of the type of transfer slip used.

User satisfaction is also affected if the transfer slip procedure requires the passenger transferring from bus to rail to wait in a long line instead of going directly through the turnstiles. Similarly, if the transfer dispensing machines are out of order, the entering passenger must wait to get a transfer from a clerk instead of going directly through the turnstiles. In either case, the rider is faced with the choice of not getting a transfer or waiting in line, necessarily reducing user satisfaction.

The method of offering reduced fare transfers can in addition affect the amount of abuse which occurs, and hence revenue which is received, even after factoring out the effects of the transfer charge. Transfers issued by machine

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[1]Massachusetts Bay Transportation Authority, Report of the Fare Review Task Force, Phase III (Boston, Mass., November 1976).

(especially in the destination station) tend to be more easily abused (with consequent revenue losses), because many extra transfer slips can be taken by an individual. Various strategies for locating the transfer machines can be tried to alleviate this problem, but it is inherent in the nature of the automated transfer slip distribution system.

13.5 Synthesis

At the present time, there seem to be three major methods of offering reduced fare for bus/bus transfers: transfer slips, daily (or longer-term) passes, and transfers without transfer slips. The first two are very common. The third alternative is relatively rare, but has some potential new applications.

Bus/bus transfers can be accomplished without transfer slips in three sets of circumstances: complete absence of reduced-fare transfers, a small number of buses which are on a pulse schedule (as in Haverhill), or a restricted-access facility (e.g., terminal) at the single transfer point on a system. Creating the first of these situations by instituting a full transfer charge clearly has fare consequences which dominate the transfer slip effects (see Chapter 12). The second situation is highly unusual, and is not a viable strategy for any but the smallest systems. There are many cities, however, in which all transferring occurs at one location in the CBD. A restricted-access, off-street terminal facility would allow reduced-fare transfers without transfer slips and their associated costs. However, such a terminal is expensive to build and could not, of course, be justified solely on the basis of the benefits received from eliminating transfer slips.

In contrast, there appear to be many viable methods for offering reduced-fare bus/rail transfers. None of them, however, are flawless. Methods for providing rail-to-bus transfers appear open to abuse in many cases, especially when the dispensing of transfer slips is done by machine. Bus-to-rail transfers generally require added labor in the rail stations, or else they cannot be offered at a reduced rate, effectively determining the transfer charge (i.e., full).

The simplest method of offering bus/rail transfers is the one which is commonly used for rail/rail transfers; that is, using no-barrier transfers with both vehicles in the same fare-paid area. This method entails no operating costs, but can realistically be implemented only at the time the station is built.

Thus, it appears that for most transit systems, there is no dominant method for offering reduced-fare bus/rail transfers.

Chapter 14
SCHEDULE INFORMATION

14.1 Introduction

The provision of schedule information is an option which is of broad general interest in transit. Providing schedule information is also an important component of a transfer policy. For this reason, this study will examine the transfer-related effects of schedule information.

Section 14.2 reviews current practice on providing schedule information to passengers transferring between buses. An important distinction is made between schedule information provided at the transfer point, and information available prior to beginning the trip. Section 14.3 extends this review to schedule information provided for bus/rail and rail/rail transfers.

Section 14.4 indicates the consequences of different methods of providing schedule information to transferees. User satisfaction is difficult to measure, but data are available on rider awareness of the transfer system. Finally, tradeoffs

that should be considered in making the decision to provide various types of schedule information to transferees are outlined in Section 14.5.

14.2 Current Practice -- Bus

Schedule information for bus/bus transfers can be provided at the transfer point, or prior to the start of the transit trip. The schedule of connecting buses at transfer points can be provided in many ways. Printed schedules can be posted (often behind a plexiglass shield), distributed by transit personnel (e.g., at main downtown transfer points), or otherwise made publicly available (e.g., through "take one please" pockets). Depending upon the exact method chosen, periodic actions may be required on the part of the operator to replace the schedules as they become outdated, depleted or vandalized. Directions to the location of connecting bus stops can also be posted.

Information about whether the connecting bus is late can be provided either by transit personnel directly or through the use of a message board. Both require that the transit system have some means of communication which can inform waiting passengers at the transfer point that the bus is late.

Prior to starting a trip, potential transferees can make use of several sources of information. Printed schedules are found on almost all properties, and many have telephone-based systems which convey schedule information, up-to-date service conditions, or both. More important for the purposes of this study, information can also be provided which makes the user more aware of potential transfer opportunities or operator actions which make transferring easier. For instance, many schedules include a small map of the route, indicating possible connecting buses. In addition, time points, often listed for

each run of the route, can be used to estimate when the bus will be at the transfer point. Printed schedules or phone contact can also supply "best connecting bus" information directly, indicating what time the rider should leave to minimize wait time at the transfer point.

Information can also be provided on operator actions which make up the other components of the transfer policy. The schedule or phone contacts can indicate which buses or routes are through-routed (although most properties which through-route do not make any attempt to communicate this information to their riders). Dynamic control and schedule coordination are almost never indicated on the printed schedules, although they could be. Some properties which use pulse scheduling have schedules which list only the departure time for the pulse, while others have schedules which omit mentioning entirely that pulse scheduling is in effect. In many cases the schedule also does not supply the information that buses are held to guarantee connections. However, most schedules do indicate the transfer charge and the procedure for transferring (i.e., take a slip before leaving the first bus).

There are several reasons why operator actions to make transferring easier are not more extensively publicized. In the case of through-routing, operators are worried that changes in demand patterns will necessitate changes in the headway of one route of a through-routed pair. If the through-routed pair has been officially acknowledged and has built up ridership, breaking it up will lead to user complaints and poor public relations. Another transfer policy component, dynamic control, is seldom publicized for fear of attracting extensive use and causing excessive perturbations to the system. The operator typically does not want to commit himself to actions which he views as secondary, and would rather retain the flexibility to

use the option selectively. A belief on the part of a rider that (s)he was "entitled" to benefit from dynamic control could lead to excessive frustration and poor public relations if system efficiency considerations preclude its use for that particular trip.

In view of the lack of information about the current transfer policy, most riders must obtain their information through word-of-mouth and personal experience. This is consistent with the way most transit information is obtained, according to recent results obtained in transit market research[1], as well as with the attitudes of transit operators. The general feeling is that regular riders and transferees will be aware of the transfer policy without it being formally publicized. Relatively few properties make special efforts to disseminate their transfer policy information to infrequent riders or nonriders.

14.3 Current Practice -- Rail

All of the schedule information options reviewed in the previous section for bus/bus transfers can be applied to bus/rail and rail/rail transfers as well. In addition, there are some methods of schedule information provision which are utilized only for bus/rail and rail/rail transfers.

As before, the methods of providing schedule information can be divided into those based at transfer points, and those employed before the start of the transit trip. One type of

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[1]See, for instance, Dick Twedt, "How Long Do Customers Carry Grudges?" American Marketing Association 10th Annual Attitude Research Conference, 1979.

information which can be provided at a bus/rail transfer point is a map in the rail station showing where connecting buses stop at the station. It is particularly helpful for rail passengers to know where they can find their connecting buses, because of the substantial negative effects of spatial separation. Several properties have provided schedule information of this sort at their rail stations. One of the more ambitious was New York City, which experimented with back-lit maps specifically for rail/bus transfers at major bus/rail transfer points. Due to the design, however, the maps were difficult to replace when bus routes were changed.

Another action which can be undertaken at rail transfer points is providing information about whether the connecting train is late. This can be done through the use of loudspeakers, message boards, or transit personnel directly. A final form of transfer point information is signing at rail stations to aid passengers transferring between rail vehicles.

Information can also be provided before the start of the transit trip. One type of printed schedule information which is frequently provided for bus/rail and rail/rail transfers is the "best connecting vehicle." For instance, in Cleveland the schedules of some buses which intersect the rail line show what bus the inbound rider must take to arrive downtown by rail at a particular time, and what train the outbound passenger must take to catch a particular bus. For both bus/rail and rail/rail transfers, the walk time required must be estimated conservatively so that the great majority of transferees can, in fact, make the connection.

In Philadelphia this type of schedule information is taken one step further through provision of both best connecting vehicle <u>and</u> best transfer point information. A brochure is published describing how to travel between the CBD and an outlying town (a trip requiring rail and bus). During the

week, there may be three possible transfer points at which buses which go to the town intersect the rail line. For many rail trips outbound, the brochure shows which transfer point and bus will give the fastest connection to the town. For trips in the opposite direction, the brochure shows which bus must be taken to which transfer point to make the fastest inbound trip. In both directions, the time of arrival of the connecting vehicle at the destination is listed.

It should be noted that few properties which use rail to bus schedule coordination at bus/rail transfer points inform their riders of which train leads to the minimum transfer time. Since the ratio of trains to buses is typically two or three to one (see Chapter 11), the uninformed rider will only be able to take advantage of the schedule coordination through random chance. However, most properties seem to feel that the frequent riders will know which trains are schedule-coordinated, and make use of them.

14.4 Consequences

Bus Transfers

Costs

The costs of providing schedule information are both direct and indirect. The direct costs include printing schedules, manning telephones, drawing and printing maps, installing and (re)filling plexiglass schedule holders. The indirect costs are subtle, and can be thought of as a type of opportunity cost: since an operator has publicly stated a transfer policy, he often feels committed to it even when it becomes unproductive. Whether or not this is true in all cases, it is clear that indirect costs of this type must be considered.

User Satisfaction

It is only possible to indicate in a qualitative way how user satisfaction changes with different methods of providing schedule information. In the case of information provided at the transfer point, the effect is to inform the transferring passenger how long he/she has to wait for the connecting bus. Just having this information may raise the transferee's user satisfaction by limiting uncertainty. It also may have the further effect of freeing the transferee to engage in other activities (e.g., shopping) until the bus comes. If such alternative activities are available, the provision of schedule information could be equivalent of a significant reduction in wait time, although no quantitative evidence is available to test this hypothesis.

Awareness of schedule information prior to the start of the trip has somewhat different effects. Passenger behavior and perceptions, and hence user satisfaction, are likely to be affected if the transferring passenger is aware beforehand of where the transfer points are, and how long the expected transfer wait time is. Moreover, if the passenger is aware of available through-routing, schedule coordination, dynamic control, or timed transfers, he may adjust his route or time of departure to take advantage of them, thus raising his user satisfaction.

There is some quantitative evidence available concerning the awareness of riders and nonriders regarding transfer policies. For example, in Brockton, a property which has had a highly publicized pulse scheduling system for several years, a survey of riders and nonriders obtained perceptions about transfer policies and service levels.[1] Only 11 percent of

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[1]Multisystems, Inc., BAT Marketing Study, prepared for Brockton Area Transit (Cambridge, Mass.: Multisystems, Inc., September 1978).

nonriders believed that the transfer wait time was between 0 and 5 minutes. More surprisingly, only 35 percent of riders were aware of the pulse scheduling. Likewise, only 23 percent of nonriders and 45 percent of riders knew that transfers were free.

Given that Brockton publicizes its transfer policy extensively, these results imply that riders on many properties have an even lower level of awareness of transfer policies. It is reasonable to assume that word-of-mouth and personal experience are the best sources of information for regular riders making their regular trips. However, it appears that a large number of infrequent riders or transferees would benefit substantially from more formal procedures for disseminating information about the transfer policy.

A final relationship between schedule information and user satisfaction concerns situations when changes are made in transfer policy. Consider, for instance, the case where an operator through-routes two routes, publicizes this action as a formal policy, and then decides that the two routes have to be unlinked because of demand shifts. Transferring riders may be less satisfied than they were before they were aware of the through-routing because long-term decisions (e.g., concerning auto ownership) may have been made based on the existence of the through service. In at least some cases, the net dissatisfaction reported from such events has been significant. Operators are therefore reluctant to imply the permanence of a given transfer policy by documenting and publicizing it.

Ridership and Revenue

Ridership will generally increase only as the result of information provided prior to departure on the trip. Information supplied at the transfer point will rarely affect whether the trip is taken, unless the infrequent user counts on

the information being available at the transfer point. If information is supplied before the potential trip, the perceived inconvenience of a transfer can be lessened by the awareness of different transfer options. This can lead to increased ridership by infrequent users who were formerly deterred by the need to transfer.

Rail Transfers

The consequences of schedule information for bus/rail and rail/rail transfers are generally the same as those for bus/bus transfers described above. The few exceptions are caused mainly by rail's fixed facilities and higher service frequency of rapid rail. Because rail facilities are fixed and service is often very frequent, provision of rail schedule and route information (for transfers to rail) is at the same time easier to provide but less important than schedule and route information for transfers to bus. On the other hand, because it may not be immediately obvious to the rider transferring from rail where the connecting route stops, signs and directions within the facility can raise user satisfaction.

14.5 Synthesis

If the schedule and routes of a transit system never changed, provision of schedule information of all types would clearly be the preferred action. The direct costs of providing schedule information are generally minor (except perhaps in the case of a large telephone-based information system), and positive user satisfaction and ridership benefits would result. In particular, riders could be informed about all of the user benefits accruing from the transfer policy without fear on the part of the operator of future inefficiencies or public relations problems.

However, when change occurs on a regular basis on the transit system (as it typically does), the decision to provide schedule information needs to be examined more carefully. Change can be caused by a number of different factors: demand shifts, increases or decreases in available funds, increases or decreases in available vehicles, new labor contracts, etc. Schedule changes will in turn require adjustments in the information provided. These adjustments have negative direct cost consequences, caused by the need to print new schedules, replace them at transfer points, etc. The satisfaction of previous users may also decrease with the change, or else costs are effectively increased if pressure from users forces unproductive policies and actions to be maintained.

From the viewpoint of providing information relating to transfers and transfer policies, the key factor in the information/cost tradeoff is the rate at which each facet of the system changes. Route structure, for instance, is usually more stable than schedules, so listing transfer points in a schedule is less of a problem than listing schedules of connecting routes, especially in the case of rail routes. Also, the "best connecting vehicle" may change as the result of a small change in the schedule. This may account for the fact that few properties put "best connecting vehicle" information in their printed schedules.

Each operator must determine whether providing information about a particular component of his transfer policy is ruled out by the need to make periodic adjustments in schedules and routes and thereby void implicit "promises" which are made by formally publicized policies. In the absence of any such overriding reason not to inform the riding public about operator actions which make transferring easier, supplying such information can only raise user satisfaction, ridership, and revenue.

Chapter 15
MARKETING

15.1 Introduction

The final transfer policy component to be considered in this study is the use of transfer-related marketing initiatives by the transit operator. Such incentives might focus completely on transfers, be part of a broader marketing effort, or utilize transfers incidentally to market other aspects of the transit system. The consequences of such incentives again cover cost, user satisfaction, ridership and revenue.

Section 15.2 explores the transfer-related marketing initiatives implemented or proposed by operators of both bus and rail transit properties. There have been only a few cases in which transfers were the focal point of a marketing effort, and these have occurred only when the transfer policy has some important distinguishing feature. However, use of transfers as part of other marketing initiatives is relatively common. It is thus difficult to isolate the transfer-related costs of marketing efforts. User satisfaction, ridership, and revenue gains from transfer-related marketing are, however, possible and are discussed in Section 15.3.

15.2 Current Practices -- Bus and Rail

Transfer-related marketing initiatives which focus primarily on some aspect of the transfer system are rare. When such a focus occurs, the aspect must be somewhat unusual, and must potentially affect a significant proportion of riders systemwide. Transfer charge and pulse scheduling are the two systemwide components of a transfer policy most likely to become the object of a marketing campaign.

In Chicago, the Regional Transit Authority "Universal Transfer" provides one example of a situation in which adoption of reduced-fare transfers between different carriers has been marketed. When it was introduced in 1976, the Universal Transfer was marketed by means of brochures, car cards, and newspaper ads.[1] In 1977, it was made the centerpiece of another marketing campaign that aimed to increase use and awareness of the Universal Transfer by means of television and newspaper advertisements. Although other properties have marketed changes in their transfer charge, these usually are part of a wider fare change so that the transfer charge is not a significant part of the marketing effort.

Pulse scheduling, because it is a pervasive component which affects route, schedules and transfer wait times systemwide, also has been the focus of marketing efforts. Brockton and Westport in particular have made pulse scheduling key elements of their marketing strategies, although both give attention to other facets of their system. Pulse scheduling is marketed on the basis of its simplicity and comprehensibility, as well as because of the shortened transfer wait times. Again, the marketing media have included newspaper ads, car cards, and the like.

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[1] Brian Cudahy, "The Universal Transfer: Getting Around the Chicago Area," Transit Journal (Summer 1977).

In addition to the time and cost attributes of transfer policy options, it is possible to market the transit system's "responsiveness." That is, the "minor" version of schedule coordination, in which individual runs are adjusted to promote user satisfaction, is an excellent way to influence attitudes of users and nonusers alike. Even if few such changes are actually made, the indication that the institution is *trying* to be responsive to user needs almost always has strong, positive effects.

Many properties promote transfers as part of broader marketing efforts. For instance, properties often produce brochures describing their special services, including brochures on how to transfer. The transfer policy can also benefit from advertisements and schedule information distribution, which are not primarily directed toward transfers.

Transit fare prepayment (TFP) plans are an important example of transfers being marketed as part of a larger effort. These plans usually promote ridership by offering the frequent rider a discount on the basic fare. A side effect is often that the transferring rider can receive free transfers. However, depending upon modal, directional and temporal restrictions on the passes (e.g., no counterflow riding during peak hours), TFPs may promote overall ridership without having major transfer-related effects.

Transfer slips can also be used as part of marketing campaigns which have nothing to do with transfers. For example, a special promotion might be organized in which retail establishments offer their customers return fares in exchange for transfer slips. Or properties might allow their transfer slips to be used as daily passes on weekends. Depending on the regular transfer charge, such a daily pass may not encourage transferring *per se*, but would serve as a marketing tool for promoting overall ridership.

These examples of transfer-related marketing are not meant to be all-inclusive. Marketing initiatives are limited only by the imagination of the operator, and vary from property to property according to the goals of the operator, the characteristics of the system, and the resources available. However, these examples span the range of transfer-related initiatives and suggest types of marketing initiatives that can be implemented.

15.3 Consequences

Cost

As was stated in the introduction to this chapter, reliable estimates of the costs of transfer-related marketing efforts are site-specific and specific to the marketing program. However, it should be pointed out that transfer-related marketing can often be accomplished at low cost. Radially-oriented transfer systems, for instance, typically have many fewer transfer points than bus routes, making it simple to explain the transfer component of the system. On the other hand, it is possible to spend significant amounts on transfer-related marketing, especially when not mounted as part of a wider marketing effort.

User Satisfaction

Marketing can cause changes in awareness, attitude, and behavior on the part of users and nonusers. Transfer-related marketing has proven successful on many properties not only in affecting attitudes towards transfers, but also toward other facets of the transit system.

Consider first the effects of transfer-related marketing on user awareness. Marketing has been used to raise the awareness of different market segments regarding the existence of reduced-fare transfers, pulse scheduling, and other

components of the transfer policy.[1] At the same time, some operators have found that such marketing can make people aware of the coverage and services provided by the system as a whole. This effect may be accentuated if the marketing effort is directed toward market segments which use only part of the transit system (e.g., for CBD-oriented work trips) or who only ride infrequently.

Transfer-related marketing efforts can also affect attitudes and perceptions. For instance, marketing can alter the perception that transfers are onerous by promoting aspects of the transfer policy which make transfers easier. This is especially useful on properties with low-frequency routes, where, unless they are informed otherwise, people may assume that they will have a long wait for the connecting vehicle.

Transfer-related marketing has also been directed toward changing attitudes not related to transfers. For instance, on one property the fact that all buses pulsed at one central point in the CBD was used to focus attention on the CBD itself with the objective of inducing development there. Pulse scheduling thus was used as a tool in a much broader marketing effort.

Ridership

Increased ridership is another possible result of transfer-related marketing. For example, those systems using pulse scheduling which have experienced large gains in ridership are those which marketed the distinctive features of the transfer. Also, the Chicago RTA Universal Transfer marketing campaign produced a 50 percent rise in the use of the

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[1]For instance, a two-month marketing campaign in Chicago for the RTA Universal Transfer raised awareness of it among a random population sample from 15 percent to 52 percent.

transfer over a two-month period. Furthermore, the use of transfer slips in Milwaukee as a Sunday all-day pass (at a single fare) produced large increases in ridership. Thus, marketing efforts which focus on transfers and those which use transfers incidentally both have the potential of changing behavior and attracting ridership.

It is unclear which market segments are most likely to change their riding behavior as a result of transfer-related marketing efforts. On complex systems, many transit-riding segments may be affected by a marketing campaign if it increases the awareness and comprehensibility of the system. Groups of transit riders who transfer infrequently may be induced to ride and transfer more for discretionary trips. Finally, some groups of nonriders may respond to transfer-related marketing, especially those which include reduced-fare and/or wait time components.

Revenue

There are two types of revenue effects which occur as the result of transfer-related marketing. Obviously, if new full-fare ridership is attracted, revenues will increase. On the other hand, if the marketing campaign includes a reduced-fare promotion of some type, revenues will not necessarily follow the increase in ridership. In these cases, it must be determined whether the gain in revenues from increased ridership covers the loss in revenue from the reduced-fare promotion. Some properties claim to have increased their net revenue through reduced-fare transfer-related promotions, not even counting the long-term effects of increasing people's awareness of the system, and getting more people "experienced" with transit. Of course, in order for these promotions to have beneficial long-term effects, the quality and reliability of service promised in the promotion must, in fact, be delivered.

15.4 Synthesis

There are tradeoffs which the transit operator must consider when deciding whether to implement transfer-related marketing. On one side is the cost and administrative effort involved in mounting a marketing campaign. These costs may be minor, of course, if the transfer aspect is part of a larger marketing effort. On the other hand, there are several factors which would render transfer-related marketing worthwhile. If the transfer system has distinctive features, such as pulse scheduling, transit malls, transfer slips which entitle the holder to other privileges besides transfers, and transfers which are good on more than one carrier, marketing may be productive. Anything out of the ordinary about the transfer system may provide a good focus for the marketing campaign if it improves the typical level of service, is discrete and easy to explain, and does not provide an opportunity for overuse which would be detrimental to the system (e.g., see the earlier discussion on dynamic control in Chapter 8).

Any particularly onerous feature of the transfer system may also justify a marketing effort. For instance, if an operator is altering the route structure in such a way as to increase the number of transfers needed (i.e., bus route consolidation at rail stations), marketing efforts which explain why the change could help mitigate this problem. When transferring passengers must walk a significant distance to transfer, marketing can lessen their uncertainty about where to go, or about the environment, and highlight productive opportunities which exist on such a walk. In such cases, the marketing may have positive effects beyond mitigating the onerous aspects of the transfer.

It remains uncertain, however, whether marketing directed toward transfers is appropriate on properties whose transfer system has no special attributes. It is always possible to run a promotion which utilizes transfer slips, as in the case of all-day passes or retail promotions, and these will usually be worthwhile. However, simple marketing of the "ordinary" service which most potential users are aware of is not likely to be productive.

This concludes the draft report on the state of the art of transit transfer policies and costs. Demonstration recommendations and operator guidelines for bus/bus and bus/rail transfer policies are also being produced.

Appendix A
TRANSFER BIBLIOGRAPHY

The following bibliography contains the important transfer-related materials which have been reviewed for this study. The references are organized into categories according to their areas of applicability to this work. The first category represents demand-side literature utilized in the study. The second contains references which address bus/bus transfer issues. The third focuses on references relating to bus/rail and rail/rail transfers. In the fourth, general transfer-related background material is cited. The fifth category contains general background information for various cities and transit operations (not including TDPs). The sixth and final category consists of other transfer-related bibliographies.

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